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INTRODUCTION TO GEOLOGY,

AND ITS

ASSOCIATE SCIENCES.

DESCRIPTION OF THE FRONTISPIECE.

THIS delineation, which was designed, drawn, and engraved on the wood by MR. NIBBS, represents the shores of that ocean by which the strata of the oolite and lias were deposited. Rocks appertaining to these formations constitute the heights and cliffs; and the vegetation consists of those trees and plants the remains of which are discovered in these deposits, including palms, tree-ferns, pandani, and coniferous trees; together with the smaller plants, as the ferns, cycadeæ, &c. &c.

The reptiles comprise the ichthyosaurus in the act of devouring a fish; the plesiosaurus, which has seized a pterodactyle, or flying reptile, on the wing; together with crocodiles and alligators, which are depicted on the shores. Turtles and tortoises are prowling on the banks, and the waters of this primeval sea are tenanted by corals, shells, crustacea, and fish, appropriate to this peculiar period of the history of nature.

The artist, it is obvious, has equalled the spirit and vigour of his design by the strictly correct and successful execution of its details.

THE AGE OF REPTILES

AN INTRODUCTION

A. S. Taylor

TO

Monkelly

GEOLOGY,

AND ITS ASSOCIATE SCIENCES

MINERALOGY, FOSSIL BOTANY, AND PALÆONTOLOGY.

BY THE LATE

G. F. RICHARDSON, F.G.S.

Of the British Museum.

A New Edition, Revised and considerably Enlarged,

BY

THOMAS WRIGHT, M.D.

Member of the Royal College of Surgeons; Senior Surgeon to the General Dispensary, and President of the Literary and Philosophical Institution, Cheltenham.

LONDON:

H. G. BOHN, YORK STREET, COVENT GARDEN.

1855.

LONDON:
BRADBURY AND EVANS, PRINTERS, WHITEFRIARS.

THE EDITOR'S PREFACE.

THE distinctive character of this popular work consists in the condensed view which it gives of Mineralogy, Fossil Botany, and Palæontology, considered in their relation to the Natural History of the Earth. Keeping the Author's original object in view, the Editor has endeavoured to render the text still more concise by excluding all irrelevant matter; and has thus gained space for considerable additions, especially to the chapters on the Tertiary, Cretaceous, Wealden, Oolitic, Liasic, Devonian and Silurian groups.

The article, Palæontology, has been entirely re-written, and the best authors on the subject carefully consulted. In this the Editor has been especially indebted to the admirable *Traité Elémentaire de Paléontologie* of Professor Pictet, Cuvier's *Ossements Fossiles*, Vogt's *Lehrbuch der Geologie und Petrefactenkunde*, Goldfüss's *Petrefacta Germaniæ*, D'Orbigny's *Cours Elémentaire de Paléontologie*, and the works of our distinguished countrymen, Professors Owen and Grant, Sir C. Lyell, Sir R. Murchison, Sir H. De la Beche, Dr. Mantell, and Professor Sedgwick.

A considerable number of woodcuts have been added, especially to the Palæontology and special geology; as good figures are of great importance in imparting clear ideas on these branches of Natural Science.

May, 1851.

PREFACE TO THE SECOND EDITION.

The motives which originally induced the author to prepare this volume for the public were briefly these. During the course of some experience as a lecturer on geology, he had constantly been in the habit of recommending the various works already published on the science, and had as constantly been requested to name some treatise more particularly intended for the tyro, and more expressly designed to convey that preliminary information which the mere beginner is so anxious to acquire. Not being aware of the existence of such a production, and being naturally desirous to comply with a demand so strongly and so extensively urged, he undertook the present publication; which, in addition to its claims on the attention of the novice, its adaptation for the use of schools, and of classes in literary and scientific institutions, would, it was hoped, be found not wholly devoid of interest for those who had already attained some proficiency in the science.

The flattering approval of the public press, the favourable manner in which the volume was received by the public, and the sale of a large impression in a comparatively brief space, have proved the correctness of these anticipations, and have induced the author to publish the present edition; which, beside a large increase of letter-press, contains a new frontispiece, with nearly one hundred new wood engravings,

and is offered to the public at a reduction of two shillings in price.

The writer thinks it proper to mention that the whole of the additional wood engravings were drawn, as well as engraved, by Mr. G. H. Nibbs, with the single exception of the vignette, for which he is indebted to the pencil of Miss Plowman.

In submitting the volume to the public, the reader is again respectfully reminded that the work is one of the most elementary character,—that it is designed merely as an introduction to others of far superior merit,—and that the highest objects of the writer will be attained, if, by means of its pages, the reader should become acquainted with the admirable and judicious reasonings of a Buckland,—the philosophic speculations of a Lyell,—the splendid oratory of a Sedgwick,—the fascinating eloquence of a Mantell,—the talented writings of a Phillips,—the able and energetic researches of a Murchison,—the instructive publications of a Fitton, a De la Beche, a Bakewell, and of many, many more, of whom science and literature may be justly proud, and who may be regarded as ornaments to letters and philosophy, and benefactors to the whole family of man.

Memnonium, or Head of Rameses, in the British Museum, showing the passage of greenstone into syenite.

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INTRODUCTION TO GEOLOGY.

CHAPTER I.

Outline of the Work—Definition of Geology—Vindication of the Science, as a Useful and Practical Pursuit—Connexion of Geology with National and Commercial Prosperity, Mining, the discovery of Coal, Civil Engineering, Agriculture, Drainage, Artesian Wells, Health and Salubrity, Architecture, the Arts, Literature, Mental Discipline—Exercises on the above subjects.

Outline of the Work.—It may be desirable to state, at the commencement of this volume, the arrangement proposed by the author in its composition, which is, in substance, the same that he has found most eligible when delivering lectures on the science. The present chapter will comprise a definition of geology; an endeavour to rescue the study from certain objections and prejudices undeservedly attached to its pursuit; a vindication of its practical advantages, and proofs of its relation to the wants and utilities of life. The next will afford a brief outline of its history; and will be followed by others, conveying miscellaneous information in the form of first lessons, together with directions for procuring and describing fossils, forming a collection, and generally cultivating geological inquiries. The succeeding chapters will respectively contain an introduction to the auxiliary studies of Mineralogy, Physical Geology, Fossil Botany, and Palæontology. The mind of the student having thus been prepared with an outline of those subjects which are essential to a knowledge of Geology, the remaining pages will be devoted to a concise description of the different geological groups.

Definition of the Science.—Geology may be defined to be the inquiry into the natural history of the earth, extending through the animal, vegetable, and mineral kingdoms; and comprising, in its investigations, all time, past, present, and to come. The present explains to us the past; the past and present reveal to us the future. The examination into existing geological phenomena enables us to understand those which have occurred in past periods of our earth's history, to interpret nature by natural laws, and to appreciate agencies and results which are obscure and remote, by a comparison with such as are familiar and well known; while the study, both of the past and present, empowers us to deduce presages of the future, and to infer the nature of those changes which may occur on the surface of our planet, in future eras of its history. It may be described, in fine, as an investigation of the structure of the earth, and of the animals and vegetables which have existed on its surface.

From the above definition it will be perceived that geology is by no means to be regarded as an isolated department of knowledge, but rather as a union of all those sciences which have for their object the study of nature, and the perfections of her Divine Author. From the magnitude and importance of the objects which it contemplates, geology may be considered in grandeur and extent as inferior to none of the natural sciences; whilst, in the varied and attractive character of its investigations, it will be found to surpass them all. So diversified is the sphere of its inquiries, that it affords themes for contemplation fitted for every order of mind; and, while frequently, in the same object, it calls attention to facts which the infant understanding may comprehend, it offers problems which the loftiest intellect is unable to solve. The shell imbedded in limestone, or the vegetable converted into coal, the tyro may discover the one to be a marine, the other a terrestrial production; but the process of the conversion of that shell into limestone, while the animal matter is often replaced by flint, or the agency by which the plant has been transmuted into a mineral substance, while the woody structure is retained, involves questions which the present state of our knowledge is insufficient to determine.

In addition to other advantages which might be adduced, it must not be forgotten that geology is still a youthful and progressive study, whose investigations possess the charm of novelty, and whose discoveries are but the unfoldings of the history of the past.

Before the benefits of philosophic research were rendered so obvious as they now are, it was the fate of geology, like many other scientific studies, to be regarded as a speculative pursuit, which, however well adapted to interest the philosopher, was useless to society in general. This erroneous opinion, though now, in some degree, dispelled, is still so firmly implanted in the minds of many, who have not paid sufficient attention to the subject, that we deem it necessary to devote some of our earliest pages to a brief statement of the relation of geology to several of the most important pursuits of life.

Dependence of National Prosperity on Geological Position.—The social condition and commercial prosperity of a people is often in a great measure due to the geological structure of the region of the earth they inhabit. Of the truth of this proposition our own country is a remarkable example. We owe our high position, as a nation, not solely to the moral qualities of the Anglo-Saxon race, but to the physical advantages derived from the geological structure of our island, which by yielding us stores of metals and ores, of limestones and sandstones, of salts and minerals, and above all of coal, enables us not only to supply our own wants, but to minister to those of others, and to convey knowledge and civilisation to the very ends of the earth. From the remotest periods, when the Carthaginians and Phœnicians traded with our British ancestors for lead and tin, to the present time, the mineral and geological riches of our island have been eagerly sought by distant nations; and, at the present moment, countries the most remote from our own, and from each other, are largely our debtors for many of the benefits which they enjoy. On the sultry plains of India, and of Arabia—amidst the frozen deserts of the north—as far distant as the antipodes, and at every point between—the natives are clad in garments, and assisted by tools and implements, which the natural resources of our country, aided by our energy and enterprise,

enable us to supply. If (as has recently been remarked *) the granite of the Scottish mountains had extended as far as the South Downs of Kent and Sussex; or if the chalk of our southern shores had reached to the Grampian hills, our social and commercial condition would have presented a dreary contrast to the scene of energy, enterprise, and wealth, which it now presents. If the granite had prevailed throughout the entire island, we should have been placed in a country, picturesque, it is true, in its general outline, abounding in the alternations of mountain and of vale; of hill and of glen; relieved by the torrent, the waterfall, and the lake; and embellished with a profuse, though monotonous vegetation; while the rocks beneath would have afforded occasional supplies of precious metals, and stores of tin, copper, silver, and gold. But the climate would have been severe; its productions limited and few; its population scanty, scattered, and poor; and we should have continued a race of miners and mountaineers. On the other hand, had the chalk extended over the whole country, we should have possessed extensive pastures and sheep-walks, and should have become a community of shepherds, grazing our flocks on the hills, and cultivating a confined and partial vegetation in the valleys and fissures of the chalk. In neither case could we have attained that prosperity and eminence which we now so happily enjoy, since we should have been destitute of those natural advantages which constitute the basis of our national prosperity and power; and which, from the chalk of our southern shores to the granitic formations of the north,—from the South Downs of Sussex to the Grampian hills,—and from the clay lands of the east to the metallic districts of the west,—from the fields of Essex to the mines of Cornwall, yield a variety of benefits calculated not only to enrich ourselves, but to render us the dispensers of blessings to regions the most remote. The relation of commercial and social prosperity to geological situation has been forcibly illustrated by Dr. Buckland, who, in his Bridgewater Treatise, furnishes an outline of the chief physical features of our island, and calls attention to the striking fact, that no

* By Leonard Horner, Esq., at the Anniversary of the Geological Society, 1841.

less than nineteen of the largest and most important towns in England, from Exeter to Carlisle, are all situated along the line of one geological formation, the new red sandstone, which, in addition to its own mineral treasures of rock-salt, gypsum, soda, and metallic ores, usually covers the invaluable deposit of coal, at once yielding an incentive and supply to the vast and enterprising population of this favoured district.*

Dr. Silliman† adverts to the same point, and with patriotic zeal expatiates on the admirable resources of the vast American continent, the variety and richness of its diversified geological deposits, and the favourable prospects of its future inhabitants.

This part of our subject is so varied and important, that to follow it in all its details would far exceed our limits; and with one additional remark, illustrative of our obligations on this account to an all-bountiful Providence, we shall pass to other observations of a like nature. It is found that insular situations are usually favourable to the development of varied geological formations, while continents and extensive tracts of country are generally monotonous and unvaried. Thus, while the Isle of Arran presents an epitome of the lower secondary and primary, and the Isle of Wight a like compendium of the tertiary and upper secondary formations, Sir R. Murchison, in his recent visit to Russia, travelled for two thousand miles over old red sandstone alone. Hence, in addition to the advantages of natural security and defence, our insular position confers those of mineral resources alike diversified and beneficial. The same cause, or train of causes, which rent our island from the adjacent shores of Europe, was, doubtless, associated with intrusions of eruptive rocks, which brought with them to the surface, many of those varied and valuable deposits which enrich our favoured land.

GEOLOGY CONNECTED WITH MINING.—Among those

* A passage of Scripture has been happily applied to describe the blessings with which we are favoured by our peculiar geological position. "A land wherein thou shalt eat bread without scarceness, thou shalt not lack any thing in it; *a land whose stones are iron, and out of whose hills thou mayest dig brass.* When thou hast eaten and art full, then thou shalt bless the Lord thy God for the good land which he hath given thee."—Deut. viii. 9, 10.

† In Bohn's edition of Dr. Mantell's Wonders of Geology.

economical advantages which the science is calculated to confer, its assistance to the miner may be first adduced, since it occurs earliest in the series of geological formations. It is at once the object and the boast of geology to redeem the search after metallic ores from the hazard which in times past attended it; to teach the miner to discard the belief in sinister influences and evil spirits, by showing that mineral substances have not been distributed by chance, but that each is referable to some peculiar geological deposit, to direct the inquiry for them on fixed principles, and in conformity with the laws which regulate their occurrence. In this country, the granitic regions are the only districts in which tin is discovered in sufficient extent and abundance to justify its being sought for economical purposes. Copper is also found in the greatest abundance in granite, and in the schistose or slaty rocks above it; and the principal mines of these metals, in this country, are situated in Cornwall; though the latter substance also presents itself, but in less plenty, in the new red sandstone. Lead is chiefly confined to the carboniferous limestone: the most important supplies exist in Derbyshire and Scotland, amid strata appertaining to this formation. These metals, together with silver and others, occur in veins, which, in some cases, communicate with fissures beneath, and have, probably, been occasioned by deeply seated subterranean agency; or they are the result of the chemical segregation of metallic particles from the surrounding mass. Gold offers an exception to the general rule of metals existing in veins: it is disseminated in minute quantities throughout those rocks (usually of a quartzose character) in which it occurs, and is chiefly obtained in alluvial gravel resulting from the decomposition of such rocks, or from the sands of rivers, which, flowing over them, have washed out the particles of gold. It is in the alluvial soil on the banks of the Rio del Sacramento, that the rich gold washings occur which have attracted so many "diggers" to the shores of California, where the search is now pursued with so much eagerness and success.* Platinum, together with zircon, the diamond, and many other gems, is

* Humboldt's Views of Nature, p. 207; Bohn's edition.

also found in alluvial deposits, their original source being, probably, the same as that of gold; while iron in this country is usually associated with coal and limestone, without both of which substances it would be impossible to reduce this valuable ore to a metallic state.

The veins of mineral substances are by no means of equal extent or value in all parts of their course, but the ore is distributed in local masses and aggregations, or *bunches*, along the line of its occurrence; while in the case of tin it occasionally spreads out into a flat mass, technically called a *floor*, or on the other hand thins into mere filaments or strings, and occasionally dies out altogether, leaving the miner to infer the path he should pursue from the occurrence of veinstones or *shodes*, which, though barren in themselves, are valuable as affording a clue to the re-appearance of richer deposits. These stones are partially rounded, and apparently water-worn, and are found on the surface, or at very small depths below it. Their mineralogical characters nearly resemble those of the contents of the *lodes* or veins in the vicinity, of which they are presumed to be fragments removed by diluvial action. The proximity of veins is farther shown by certain indications, which rarely fail to point out their nearness to the surface. These are, the barrenness of the spot, the presence of shattered fragments of the stones abovementioned, and, occasionally, the harsh, metallic taste of the water of some adjacent spring. Veins of copper are usually found in connexion with an earthy, ochreous stone, locally termed *gossan*, which is of a red colour, and crumbles like the rust of iron. The peculiar substance called *killas*, which has been described as a gneiss that has lost its schistose character, and become comparatively easy and free to work, affords another symptom of their occurrence. The *lodes*, or veins, both of tin, copper, and other ores, exist most frequently in the vicinity of granite, which is called by the miners their *country*. Metallic veins, also, usually occur contiguous to axes of disturbance, and at points which exhibit proofs of the action of fire. Since these circumstances are chiefly of local nature and origin, and are dependent on the character of the individual formation to which they are referable, it will be seen that mineral substances present themselves under such diversified con-

ditions, and amid such varied difficulties of acquisition, that a right knowledge of geology can alone enable us to overcome them.

Geology applied to the Discovery of Coal.—But there is a mineral substance more precious than silver, or even gold, the occurrence and profitable discovery of which geology alone is able to determine, and that substance is coal. If the mines of the precious metals were closed to-morrow, and gold and silver no longer raised for the use of man, society, with some very considerable revolution and difficulty in the mode of adopting other representatives of value, would go on nearly as before; but deprive civilised communities of their coal, and how fatal would be such a catastrophe to the welfare and happiness of the human race! No longer would our favoured country be the great factory of the world; no longer would our commerce convey the associate benefits of knowledge and civilisation to the remotest regions of the globe; no longer should we triumph over time and space, and traverse land and ocean with a rapidity almost incredible; our steam-power would be annihilated, and with it our prosperity and supremacy as a nation; and the future historian of the revolutions of empires would date the decline and fall of Britain's power from the period when her supply of mineral fuel was exhausted, and her last coal-field consumed!

Such are some of the most important benefits connected with the discovery and the use of mineral fuel. The utility of geology consists not only in pointing out those situations in which coal may be presumed to exist, but in determining those in which it cannot possibly occur; for while the limits of the coal-producing districts have been largely and beneficially extended, by means of researches undertaken in accordance with scientific views, enterprises have been commenced by persons ill-informed on the subject, which, having been conceived in ignorance and carried on in opposition to sound geological principles, have terminated in utter failure and disappointment. Some few years only have elapsed since the deceptive appearance of lignite, in strata appertaining to the wealden formation, at Bexhill, in Sussex, induced certain parties, imperfectly acquainted with geological science, to institute a search for coal; it was not till after works of the

most extensive and costly nature had been constructed, and an outlay of £10,000 incurred, that an enterprise, hopeless from the first, was at length abandoned in despair. Many attempts have been made, from Somersetshire to Wales; and Sir R. Murchison * mentions numerous enterprises all similarly unsuccessful. In fact, there is scarcely a formation below the chalk in which researches of this kind have not been attempted. One of the most recent and ill-judged of these consisted in an endeavour made, a short time since, at the Kingsthorpe pits, within a mile of Northampton. The author was at that time lecturing in the neighbourhood, and his opinion was requested as to the probable success of the undertaking. The geological site of the locality, which is about the middle of the oolite formation, was decisive of the futility of the enterprise, and he therefore denounced it as mistaken, and strongly protested against its further prosecution. His remonstrances were disregarded, as those of a mere theorist. It appeared that a person employed to sink a well near the spot, having bored through a bed of clay, which bore some slight resemblance to the *clunch* or clay which frequently overlies the coal, had advised the undertaking; and thus, on a fact of the most common geological occurrence, the similarity of one bed of clay to another, and under the guidance of a workman, the speculation was set on foot; a joint-stock company was organised; a large amount of capital was subscribed; steam-engines were erected, shafts were sunk, and enormous expenses incurred. This was the situation of affairs during the visit of the author in 1839. The result may easily be anticipated: the works, after being extensively prosecuted, were finally closed, and the enterprise abandoned for want of funds, after an expenditure of £20,000! Such was the termination of an attempt which an acquaintance with the first principles of geology would have decided, from the first, to be fruitless. It will thus be seen that the knowledge which the geologist possesses, to determine the existence or non-existence of coal in any given locality, may be regarded as one of the most striking proofs of the importance and usefulness of the science.

* Silurian System.

Geology applied to Civil Engineering.—At the present day, when nearly the whole of the British Isles is being intersected with railroads, a knowledge of the general principles of the geology and physical geography of the region which is to be the sphere of the undertaking, are highly important to the engineer. The nature and composition of the different strata, varying as they do from loosely coherent beds of gravel, sand, or clay, to rocks of crystalline structure, will often determine the choice to be pursued in a given district: for example, when the beds are loose and porous, they are frequently to be avoided; while a rock, though hard and crystalline, may present a valuable stone for masonry, and repay the cost of penetrating. As regards the construction of these and other public works, an acquaintance with geology is found to be of such essential importance, that it now constitutes a part of the education of the engineer.

Connexion of Geology with Agriculture.—The agriculturist is benefited by that insight into the structure of the globe which geology unfolds; as the superficial soil is usually derived from the disintegration of the adjacent rocks, an acquaintance with the nature and chemical composition of strata is of utility in pointing out the best mode of cultivation. Those lands are most productive, and least liable to exhaustion, which contain a due admixture of clay, flint, and lime; but as instances are few in which nature has bestowed them in proportions best adapted for a productive soil for the growth of the cerealia, it is the study of the scientific agriculturist, by a rotation of crops, a mixture of manures, and by adding the deficient mineral body, to produce, by science, what nature has withheld.

In the all-important operation of drainage a knowledge of the strata of a district is of the first importance.

Artesian Wells.—A knowledge of geology enables the engineer to obtain a copious supply of water under peculiar conditions of certain districts by Artesian Wells, so called from their having been first introduced in the province of Artois, the ancient Artesium, in France. These wells have been so frequently brought before the notice of the public, that the simplest outline will suffice to convey an idea of the principle of their construction. The annexed diagram

represents deposits of the tertiary system,—suppose the valley of the Thames.

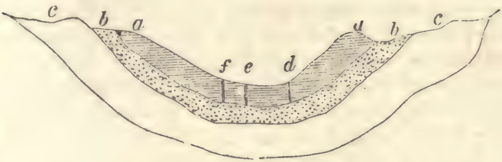

FIG. 1. Artesian Wells.

The bed, *a a*, is an impervious stratum of London clay; *b b*, a porous deposit of gravel or sand, resting on the chalk, *c c*; the whole forming a basin-like structure. The water which falls on the chalk-hills, *c c*, flows either into the chalk, or the porous bed above it, *b b*; and being forced upwards by fresh accessions, would rise to the top, were it not prevented by the clay above, *a a*. The engineer, by boring through the bed, *a a*, or the chalk, *c c*, gives exit to the subterranean water which rises to the surface and flows continually by means of hydrostatic pressure. The beds above the chalk were formerly considered to contain the water; it is now, however, ascertained that it is derived from the chalk strata beneath, and that the gault is the great retentive bed of clay that supports the superincumbent sheet of water that filters through the beds of porous chalk and firestone. By these borings through the clay beds of low, level districts in England, France, and Germany, copious streams of water are procured from depths, and under conditions, which would either preclude the sinking a well altogether, or the expense would be such as to prohibit the enterprise. The plan has been adopted with eminent success in the vicinity of London; but the most important work of the kind is in the Plaine de Grenelle, near Paris; this Artesian well yields 516½ gallons of water per minute, the temperature of which is 81° 7′ Fahr., the depth of the well is 1794 feet; the shaft passes down into the gault. The Artesian Wells in Trafalgar Square descend into the upper chalk to a depth of 393 feet.

THE RELATION OF GEOLOGY TO ARCHITECTURE AND THE FINE ARTS.—Nor is a knowledge of this science less essential to the architect. An acquaintance with its principles affords a sure guide in the selection of a good and durable building material. Many public edifices are fast hastening to decay; several of the colleges of our Universities have required to be nearly rebuilt; and many newly erected churches are in course of premature dilapidation, owing to the decomposing nature of the stone of which they are constructed; while several of our ancient edifices which have become decayed, have been repaired with so faulty a material that old and new have speedily become one ruin. The Capitol, at Washington, U. S., is in a state of disfigurement from the same cause. The evil, in this country, has grown to such a magnitude, as to have effected its own cure. The attention of architects and men of science has been called to the subject, and on the recent destruction of the Houses of Parliament by fire, a commission, composed chiefly of geologists, was appointed by government to survey the stone-producing districts, and select the best material for the construction of the new edifice. The stone recommended appertains to the magnesian limestone formation. The architectural student will find ample information in the report of the commission, and likewise in a paper on the same subject by J. C. Smith, Esq.*

CONNEXION OF THE SCIENCE WITH SCULPTURE.—The sculptor is no less indebted to geology, in the choice of material for the exercise of his art. Some of the finest productions of the chisel, owing to the choice of an unworthy material, are chipped and decomposed. The Greek marble of Pentelicus was much disfigured from its impurity and admixture of metallic oxides; but the Italian quarries of Massa and Carrara, which consist of an altered limestone, supposed to be of the oolitic series, are free from such impurities. Many ancient works of art are disfigured by the faulty nature of the material; and a celebrated *chef d'œuvre* of modern date, the Ariadne of Danneker, is spoiled from this cause. It may be added, that the late Sir Francis Chantrey was so well aware of the value of knowledge of

* Transactions of the Royal Inst. of British Architects.

this kind, that he made himself a proficient in mineralogy and geology. Even where these defects have not existed, the beauty and effect of a statue are known to depend, in a material degree, on the more or less crystalline character of the stone. We have only to place a cast, in plaster, beside the antique statue from which it has been modelled, to perceive to what an extent the expression of sculpture is enhanced by the purity of the marble of which it is composed.

To Painting.—The painter derives important aid from a science which teaches him the physical structure of a country, and the principles which determine its scenery and aspect. Many works of great merit offend the eye by departures from the truth of nature, which a knowledge of this science would have served to prevent. How absurd, for example, should we deem the error of the artist, when depicting an event which occurred in the southern district of our island, if he should sketch the scene with the rugged outline which characterises the primary formations of the north; or, if in representing an occurrence which happened in our northern districts, should he delineate the angular outline of its Plutonic rocks with the undulating lines which characterise the sedimentary formations of the south! Some of the most celebrated modern paintings exhibit faults of this description, in which rocks are drawn and views pourtrayed in localities where, owing to the physical geography of the district, they could never have existed. In fine, geology is to the painter of landscape what anatomy is to the student of animal forms, and as such will repay his investigation.

Relation of Geology to Health.—The connexion between geological structure and the salubrity of a locality must be obvious to the most superficial observer. The clean soil, clear air, and pure water of the chalk districts, form a striking contrast to the foggy atmosphere and impure waters of the London clay formation; and the dry nature of a sandy region, as compared with the moisture and malaria of a marshy district, are circumstances known and appreciated by medical men.

To Literature.—The connexion of geology with literature is evident from the distinguished merit of the works of its most eminent professors. The publications of Buckland,

Lyell, Mantell, Murchison, Phillips, Sedgwick, and others, are as much an honour to letters as to science; and the study, unquestionably, owes much of its popularity among the educated classes of society, to the intellectual powers of its great masters. It would be invidious to particularise, but the selection of a few striking instances may perhaps be pardoned. There is scarcely a more beautiful or more perfect description than that in which Dr. Buckland* depicts, with his accustomed eloquence, a Silesian coal-mine with all its splendid scenery of the graceful vegetable forms of the primeval earth. Dr. Mantell,† adopting the image of an Arabian writer, introduces an imaginary being, endowed with superhuman longevity and power of observation; and, in the person of this fictitious observer, describes the chief geological mutations of our island in a style which combines the most perfect eloquence with an accurate adherence to scientific fact. Sir Charles Lyell ‡ has a passage which forms one of those gems of philosophic truth with which the pages of this admirable writer are so profusely adorned. After noticing the remark of Lord Byron,

"The dust we tread upon was once alive,"

he observes that the philosopher transcends the poet; that while the one can only utter the vague exclamation that inanimate matter was once animate, it is the triumph of the other to describe the very form which it assumed when endowed with the faculties of existence. The works of Sir Roderick Murchison abound in the most graphic descriptions of the wild and wondrous regions he has so successfully investigated: those of Professor Phillips display the rare union of severe and minute investigation of facts, and mathematical accuracy of deduction, with the most graceful style of composition, and the most attractive charms of sentiment and feeling. A similar tribute is due to Professor Owen, to whose researches, memoirs, and publications, science is so deeply indebted; who, in his admirable orations, literally "bids the dry bones live," and invests the technical details

* Bridgewater Treatise, vol. i. p. 458.
† Wonders of Geology, fourth thousand, vol. i. p. 409.
‡ Elements, second edition vol. i. p. 57.

of anatomical and physiological investigations with all the attractions of eloquence, genius, and taste. The orations of Professor Sedgwick evince the like combination of scientific attainment with literary excellence; and the writings of various other geologists might largely increase our list. Mr. Hugh Miller* has a chapter descriptive of the influence of physical geography on the character and aspect of natural scenery, which transcends, perhaps, in force and beauty ot description, any production of a similar kind; while it exhibits, at the same time, that acquaintance with the principles of science to which the mere delineator of scenery makes no pretension.

MENTAL DISCIPLINE OF THE SCIENCE.—The highest advantages to be gained from this instructive study, consist not in considerations of benefit or of detriment, but in the intellectual advancement and moral improvement which it is so well calculated to promote, and in its power of invigorating the mind, and purifying and chastening the feelings and the heart. If the celebrated aphorism of Lord Bacon be true—that all study is to be valued, not so much as an exercise of the intellect, as a discipline of humanity; what study can be more instructive and improving than that which, by teaching us to look into the beautiful and harmonious world around us, corrects and chastens overweening opinions of ourselves, removes and dispels narrow ideas of nature, and substitutes more just views of the grandeur of creation, and the perfections of its infinite Author? The studious and the observant may deduce from its varied contemplations lessons of the highest wisdom and instruction; and our immortal bard, who has depicted almost every condition of human life, would seem to have had the modern geologist in view, and to have described with prophetic anticipation, his secluded but useful existence,

> "And this our life, exempt from public haunt,
> Finds tongues in trees, books in the running brooks,
> *Sermons in stones*, and good in every thing!"

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* On the Old Red Sandstone, p. 197.

EXERCISES.

It may be necessary to premise, that the exercises contained in the course of the following pages will consist less in the formal arrangement of questions to be proposed, and answers to be returned, than in a recapitulation of the most important statements contained in each section, with the view of impressing them more strongly on the memory, and enabling the student to apply them in a practical manner.

It will be obvious that subjects of so general a character as those contained in the preceding chapter, are little adapted for purposes of this nature, yet a few instances may, perhaps, be transferred to the common-place book of the student.

1. Vary the definition of geology, by terming it, with Sir C. Lyell, the inquiry into the materials of which the earth is composed, and the arrangement of those materials; with the collateral investigation into the races of animals and plants which at various periods have inhabited the globe; or describe it, with Professor Phillips, as the inquiry into the nature of sedimentary deposits, and their disturbance by igneous action, together with the natural history of animals and vegetables, &c., &c.

2. Collect instances of the practical application and importance of geological science, under local circumstances, in addition to the instances here described.

3. Give individual examples of the influence of geological position on the character of the inhabitants of peculiar districts. The relation of the same causes to the salubrity of particular regions, and the health of their inhabitants, may afford themes of illustration.

4. Note the relation of geological principles with the art of mining in any district with which you may be acquainted.

5. Seek either in the works of Phillips, Murchison, or

other authorities, or from your own experience or that of friends, examples of the successful or unsuccessful search for coal.

6. Instance the advantage of an acquaintance with geology, as regards civil engineering, in the construction of canals, railways, and lines of common road.

7. Study its connexion with agriculture, in the three particulars here mentioned—improvement of soils, drainage, and supply of water,—and note local instances of these relations.

8. Inspect the stone buildings in your neighbourhood, especially those of ancient date; observe their north and north-western sides, and the comparative resistance which these have offered to the action of the weather. Remark whether the stones are placed in the horizontal position which they occupied in the quarry, like a book laid on its side; or whether their position be vertical, like one placed on its edge: and if the latter, observe if the laminæ, or thin flakes of the stone, have not peeled off, and the stone decayed in consequence. Ascertain the quarries from which the material has been obtained, and the geological formation of their localities.

9. Collect examples, which are numerous, in the history of the art, of statues, busts, &c., which have but imperfectly withstood the action of time in consequence of the bad quality of the material.

10. The practice of transferring to a common-place book any facts of general interest, will speedily enable the student to form a copious and highly valuable store of information.

CHAPTER II.

Sketch of the History of the Science—Lost Work of Theophrastus on Fossil Shells—Strabo—Ovid—Justin—Livy—Errors and Superstitions—Revival of the Pursuits of Science with those of Letters—Boccaccio—Leonardo da Vinci—Fracastoro—Conrad Gessner—Agricola—Palissy—Nicolaus Stenon—Vallisneri—Moro—Soldani—Swedenborg—Hooke—Woodward—Ray—Leibnitz—Lehman—Werner—Dr. Toulmin—Dr. Hutton—William Smith—The Geological Society—The British Association for the Advancement of Science.

In offering a brief outline of the progress of this study, we pass over the extravagant representations of ancient Oriental writers; though it is probable that some of their opinions, particularly those on the antiquity of our planet, have originated, not merely in the exuberance of Eastern fancy, but have been suggested by an examination of the physical structure of the earth.

We find in the works of several of the most distinguished philosophers and poets of antiquity, frequent allusion to the phenomena of geology, and the occurrence of fossil organic remains. These remarks, however, are usually introduced with the view of illustrating other objects, and are seldom discussed as independent questions. In the destruction of ancient letters, the greatest loss which we have sustained, in this department of knowledge, probably consists in that of many of the works of Theophrastus, the writer on natural history, who, we are informed, wrote two books on fossil shells; a subject which could scarcely have failed to lead him into discussions as to their nature and origin, and the agencies by which they had been deposited and preserved. These writings are supposed to have been known to Pliny, and to have afforded him some information in that part of his history in which he treats of fossil remains. Herodotus* mentions the occurrence of petrified shells in the mountains

* Book ii. sec. 12.

of Egypt, with the view of proving that that country was once a gulf of the sea.

Xenophanes, a Greek philosopher, a native of Colophon, in Ionia, and founder of the Eleatic sect in Sicily, who flourished 535 B.C., promulgated some speculations which subsequent experience has proved to be correct. He contended for the antiquity of the earth, the vital origin of the shells which it entombs, and inferred from their occurrence the previous submergence of the rocks beneath the waters of the sea.

Aristotle had learned from preceding observers many events which had occurred in the history of our globe, and added valuable observations of his own. From these he inferred, with singular accuracy, the nature of some of the most important geological agencies; the filling up of rivers, the formation of deltas, the elevation of certain regions by volcanic agency, the conversion of land to sea, and of sea to land, and the universal law of change, were phenomena with which he was fully and philosophically acquainted. Strabo affords evidence in his writings* of having made still farther advances. In discussing the chief problem of ancient times, the occurrence of fossil shells at great elevations and remote distances from the sea, he cites, among others, the explanation of Xanthus the Lydian, that the phenomenon in question is occasioned by the diminution and retirement of the sea, in a manner analogous to the drying up of rivers, lakes, and wells, in seasons of drought. The philosophic geographer, however, repels this and a similar hypothesis of seas having burst their barriers and formed new channels, and offers in explanation a theory which, in substance, has been adopted by modern philosophers, and proved by indisputable evidence to be correct. He boldly asserts that the cause is to be sought, not in changes of the sea, but of the land. After stating the great probability of a considerable portion of the existing continents having been successively sunk beneath and raised above the level of the ocean, he adds, "The same land is sometimes upheaved, and sometimes depressed, and the sea also is similarly affected. We must, therefore, ascribe the

* See his Geography, book ii. chap. 3.

cause to the ground, either to that portion which is under the sea, or to that which is covered by it; and rather to the latter, from its being rendered more movable by moisture, and susceptible of greater change." He continues, "The real cause, I repeat, of all these changes is, that the bed of the sea is sometimes accidentally elevated, and sometimes depressed."

He subsequently enforces the necessity of consulting the existing phenomena of nature, with the view to explain the past, "such," he observes, "as are daily occurring to our observation—the deluges, earthquakes, and elevations or depressions of the bed of the sea; these are the causes of the rise or lowering of the waters." He adds, that as experience shows that not only small islets, but islands, and even parts of continents, are raised from the deep, so they may again be engulfed beneath the ocean.

Lucretius, the contemporary of Julius Cæsar, in his poem *De Naturâ Rerum*,* among a mass of theories and vague speculations, states several facts of importance. He attributes the formation of the earth, the seas, and the atmosphere to the union of elementary atoms, impelled by the laws of affinity; and though destitute of any positive acquaintance with palæontology or botany, says, that before men and existing objects lived, the earth had produced beings of extraordinary form, and vegetables of enormous size.

Ovid, in the celebrated passage of the 15th book of his Metamorphoses, while illustrating the system of Pythagoras and explaining the law of universal change, affords proof of an acquaintance with geological phenomena, comprising, in fact, a summary of almost all the causes now in operation on the earth. They are so lucidly stated and explained by Sir C. Lyell,† that the reader is referred to his excellent work for more details, a selection of the most important being sufficient for our purpose. Among the most striking are—

The conversion of land to sea, and sea to land.

The occurrence of marine shells at a distance from the ocean.

The excavation of level plains into valleys, and the destruction of hills, and removal of their detritus into the sea.

* Book v. † See the Introduction to his Principles of Geology.

The change of marshes into dry ground, and of dry ground to stagnant pools.

The issuing of springs during earthquakes, and the drying up of others.

The desertion of their ancient beds by rivers, and their re-appearance in new channels.

The uniting of islands with mainlands by the growth of deltas and new deposits.

The insulation of peninsulas by the destruction of the isthmus which previously connected them with the mainland.

The submergence of land by earthquakes, and the phenomenon of cities appearing beneath a lake.

The elevation of plains into hills.

The petrifying power of certain streams, which convert the substances immersed in them to marble.

The shifting of the site of volcanic action. "There was a time," says the poet, "when Etna was not a burning mountain, and a time will arrive when it will cease to burn!"

This celebrated description has attracted much attention; and the following lines, which commence it, have been quoted in almost every introductory work on geology:—

> "Vidi ego quod fuerat quondam solidissima tellus,
> Esse fretum; vidi factas ex æquore terras.
> Et procul a pelago conchæ jacuere marinæ,
> Et vetus inventa est in montibus anchora summis;
> Quodque fuit campus, vallem decursus aquarum
> Fecit, et eluvie mons est deductus in æquor."

The truth of the whole narrative will be generally acknowledged, with the exception possibly of the anchor found on the summit of the hills, which may be regarded as a mere poetic fable; like the beautiful but imaginary narrative of the destruction of the phœnix by fire, and its resuscitation from its ashes; or the explanation of volcanic agency, by the assumption that the earth is an animal, and that its mines of sulphur taking fire, consume its internal unctuous substances, till, these being exhausted, the flames die out for want of animal fuel! The last line, explaining the disintegration of mountain-masses, and their transport to the bed of the ocean by aqueous agency, has been noticed by Sir C. Lyell as somewhat obscure. May it be permitted to suppose

a slight corruption of the text to have taken place, and to suggest the requisite emendation? The mere change of two letters, by substituting "alluvie" for "eluvie," will render this description of alluvial action perfectly clear and satisfactory. The mistake is one which might easily have been committed by a transcriber, and which in the then imperfect state of natural science might have passed unnoticed.

Justin, to whom we owe the preservation of several curious passages of Trogus Pompeius, seems to adopt the sentiment of that historian as to the igneous origin of our planet. He is of opinion, that the refrigeration having taken place at the poles, the Scythians must have been the first inhabitants of the earth! Livy has occasional notices of natural phenomena, disfigured, however, by his prevailing superstition. He informs us,* for instance, that at the period immediately preceding the death of Hannibal, fearful prodigies occurred. It rained blood, he states, for three days in the court of the Temple of Concord, and a new island rose out of the sea opposite to the coast of Sicily. The former phenomenon is ascertained to have been occasioned by an insect, a butterfly of the genus *Vanessa*, which, on emerging from its *pupa* state, is known to emit drops of red liquor, so that a swarm of these creatures would naturally produce a shower resembling one of blood. A circumstance of like nature which occurred at Aix, in France, in the year 1608, occasioned similar alarms, which were dispelled by the celebrated Peiresc, who had paid considerable attention to entomology and the transformation of insects. The apparition of the new island has its analogy in the elevation of the volcanic isle of the Mediterranean, which rose from the deep a few years since, and shortly after sank again beneath the waters. These natural occurrences, however, which modern science can thus easily explain, so terrified the superstitious Romans, as to induce them to decree a supplication of the whole people to the altars and temples of the gods, to avert the calamities which it was feared such prodigies portended.

The occurrence of fossil shells at a distance from the sea is noticed by several of the fathers, and in particular by

* Book xxxix. c. 6.

St. Augustin and by Tertullian, who adduce them in proof of the deluge.

The knowledge of the subject possessed by the ancients, of whatever value or interest it may have been, was entirely lost during the benighted ages which succeeded, when the darkest ignorance prevailed respecting our earth, and the monuments of its physical history were associated with tales of the grossest and wildest nature.

It may, perhaps, be permitted in a work such as the present, devoted to the use of the student, to enumerate a few of the legends which referred the phenomena of nature to the superstition of the times. There is, in fact, scarcely a single fossil object which is not in some way mixed up with absurdities of this kind. Thus Pliny relates, that the tubular pointed shell *dentalium* was supposed, if used as a toothpick, to afford an infallible remedy for the toothache. The ammonite shells were believed to be so many petrified snakes, and the history and mystery of their fate was conceived to be that, as they abounded in the vicinity of Whitby in Yorkshire, near the abode of St. Hilda, and constituted a very considerable annoyance, the inhabitants requested the saint to use her efforts that the nuisance might be abated and the snakes destroyed, with which prayer the lady graciously complied, by first praying their heads off, and then praying them into stone! The legend is recorded in the poetry of Scott:—

> "And how the nuns of Whitby told,
> How of countless snakes, each one
> Was changed into a coil of stone—
> When holy Hilda prayed,
> Themselves within their sacred bound,
> Their stony folds had often found."
>
> MARMION, Canto II.

To so late a period did this superstition prevail, that the author of a modern scientific work,* relates the instance of a dealer, who having been requested by his customers to supply them with some of the creatures which had escaped decapitation, contrived to manufacture some heads of plaster of Paris, and affix them to the specimens; and thus

* Sowerby, Mineral Conchology, v. ii, p. 9.

pursued a thriving trade, till some remorseless geólogist, who visited the place, not only beheaded the reptiles, but showed that they were in reality fossil shells. They are now manufactured at Whitby by filing the extremity of the last whorl into the shape of a snake's head, and the accompanying illustration is from a specimen recently procured from that place.

FIG. 2.

Another legend, referring in like manner to a familiar fossil object, is also mentioned in the above poem. The fragments of the stems of *crinoidea* so commonly found in the older deposits, being hollow, were frequently strung and used as rosaries in the middle ages; they were called St. Cuthbert's beads, and are thus mentioned:—

> "Nor did St. Cuthbert's daughters fail
> To vie with them in holy tale
> * * * *
> On a rock by Lindisfarn,
> St. Cuthbert sits, and toils to frame
> The sea-born beads that bear his name."
>
> MARMION, Canto I.

These fossils bore, in Germany, the several names of *spangensteine* or bead-stones; *roeder-steine* or wheel-stones; *Bonifacius-pfennige* or St. Boniface's pennies, being found in great numbers on a mountain near Ganserode in the neighbourhood of Frankenhausen, which mountain obtains its name from that saint; while in Westphalia they are called *hünenthränen*, from being considered the petrified tears of the giants. They are also variously termed millstones, cheesestones, basketstones, caskstones, &c., from their presumed resemblance to those objects.

The echinites were severally termed *ombria*, from the Greek word ομϐρος, signifying the heavy rain in which they were supposed to fall; *brontia*, from βροντη, the thunder in

which they were also believed to be thrown to the earth; *ceraunii lapides*, from κεραυνος, the lightning by which they were presumed to be generated and formed in the air; *chelonites*, from the resemblance in their sutures to the shells of the tortoise; and *ova anguinum*, from having been considered by some as the eggs of serpents.

Various virtues and supernatural powers were attributed to different minerals and fossil remains. They were worn as amulets and relics, and an especial value was assigned to the mineral *harmotome*, or cross-stone, on account of the sacred emblem of which it was supposed to be the type. Pliny relates that the Ethiopians attached great sanctity and value to ammonites, whether converted to stone or iron pyrites. They are still venerated in like manner by the Hindoos. The *nummulite* was the subject of many a German legend under the name of the *bauern-pfennige*, or peasant's penny, and *teufelsgeld*, or devil's money, under which appellation it was equally known. In certain parts of Spain, as recently as 1835, many individuals wore the shells of *terebratulæ* in their pockets, as an infallible specific against cholera! The petrified teeth of sharks were conceived to act as a charm against various maladies. Under the name of *glossopetræ* they were believed to be the tongues of serpents or birds. At Malta they were supposed to be those of vipers petrified by St. Paul; while at Krain they bore the name of *teufelsklauen*, from an idea there entertained that the evil spirit had torn his claws in the clefts and crevices of the mountain. The list of delusions may perhaps be closed with the fact that the occurrence of the remains of the elephant and mastodon in superficial deposits, and the casual resemblance of the teeth of the latter animal to those of the human species, have probably given rise to the fables which prevail in the mythology of all nations, of the existence of giants, who, having warred against the gods, were overcome by their celestial opponents, and crushed beneath the rocks. The most recent imposture is the skeleton which, in the reign of Louis XIII., was pretended to be that of Teutobochus, king of the Cimbri, who fought against Marius. The following are the circumstances which gave rise to the tale:—

On the 11th of January, 1613, in a sandpit near the

Château de Chaumon, between the towns of Montricoux, Serras, and St. Antoine, some bones were found, several of which were broken by the workmen. A surgeon of Beaurepaire, named Mazurier, informed of this discovery, possessed himself of the bones, and contrived to turn them to good account. He gave out that he had found them in a sepulchre, thirty feet in length, upon which were inscribed the words "*Teutobochus Rex.*" He added, that at the same time he found fifty medals bearing the head of Marius. He published these stories in a pamphlet, by means of which the curiosity of the public being aroused, he exhibited, for money, the bones of the pretended giant at Paris and other cities. Gassendi mentions a Jesuit of Tournon as the author of the pamphlet, and proves that the pretended antique medals were fabricated, their inscriptions being in Gothic letters instead of Roman.—As for the bones, after having been exhibited as above-mentioned, they were put by in a chest at Bordeaux, and it was not till after the lapse of two centuries, in destroying a theatre, "*La Salle de Molière,*" a few years since, in that city, that these royal remains were rediscovered, when they were recognised to be those of a mastodon. The list of works cited by Cuvier as having been written during this controversy is long and curious.

The celebrated naturalist Scheuchzer, who, with very considerable talents and attainments, possessed an equal share of credulity, wrote a treatise on a fossil skeleton, under the title of *Homo Diluvii Testis et Theoscopos*, the object of which was to prove the remains in question to be those of an individual who had been destroyed by the deluge, but which Cuvier decided to belong to a salamander, of extinct species and enormous size. A similar specimen is placed in the British Museum (Mineral Gallery, room iii. case 1). The accompanying illustration depicts the subject of Scheuchzer's treatise.

On the fall of the Roman empire, the natural sciences were cultivated with some degree of success by the Orientals; but we have no evidence that they acquired any further knowledge of the structure of the earth than was possessed by the Greeks and Romans.

After the revival of letters the phenomena of geology began to engage the attention of the nations of the West.

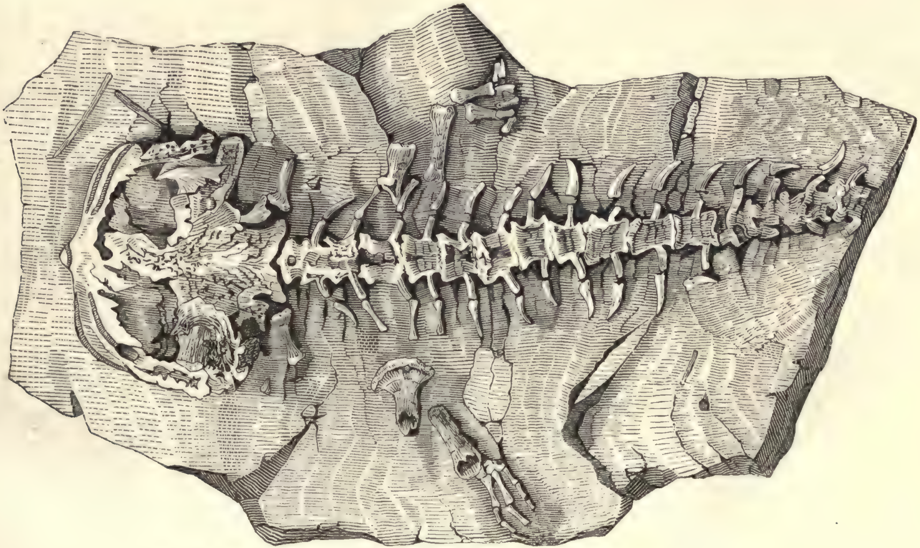


Fig. 3. Homo Diluvii Testis of Scheuchzer. Andrias Scheuchzeri of Tschudi.

Among the earliest inquirers, Brocchi* informs us, there are two, of whom letters and the arts may be justly proud. Boccaccio, born at Certaldo, a small town of Tuscany, must have been accustomed from his childhood to observe the immense assemblage of fossil shells, of which the hills of that region are composed. In his romance of "Filocopo" he describes them with much emphasis, adducing them as proofs of the sea having once covered the land.

The celebrated painter LEONARDO DA VINCI, who united the avocations of an architect and civil engineer with that of an artist, and had thus become acquainted with the structure of the earth, eagerly took part in inquiries of this nature: an opinion having been expressed that these objects owed their origin to the stars, he denounced it as absurd, and ridiculed the idea of such a cause being sufficient to produce the occurrence of different petrifactions in the same spot, as leaves, sea-weeds, and crustacea.

FRACASTORO, a celebrated physician and naturalist of Verona, in 1517 took part in the two grand disputes then prevailing. The first was, whether fossil shells belonged to animals which had lived and multiplied on the spot where these relics were found; a proposition, the affirmative of which he strongly maintained. The second related to the question whether these phenomena were caused by the deluge, a notion which he as strongly opposed, contending that the transient nature of the flood, and the fluviatile character of its waters, were calculated merely to strew such objects over the face of the earth, but were insufficient to bury them in the strata of mountains, at the depths in which they now lie entombed. Science, which had revived in Italy, soon diffused itself in other regions; and Germany, a country abounding in mines which presented admirable facilities for investigating the structure of the earth, produced philosophers, whose ardour and genius contributed in an important degree to the advancement of philosophical knowledge.

CONRAD GESSNER, born at Zurich, 1516, was one of the most learned and gifted men of his time. He is usually termed the Pliny of Germany; and when we consider the

* See his Introductory Discourse to the Study of Fossil Conchology in Italy.

comparative shortness of his life, the variety and extent of his attainments, and his proficiency in literature and philology, as well as in medical and natural science, we must acknowledge that while he resembled the immortal Swede in the ardour and success of his inquiries, he may be said to claim the pre-eminence for the wider range and greater universality of his merits. His biography presents events of considerable interest: born of poor parents, his father being a furrier, he was assisted in completing his education by his maternal uncle, Jean Frick, a minister, who perceived his dawning genius, and instructed him in literature and in botany as it was then known. But his uncle having died, and his father being killed in the battle of Zug, the youthful student saw himself compelled to seek his fortune abroad, and to finish his studies by the aid of charitable sympathy and private friendship. He was thus indebted to the kindness of the canons of Zurich, and to a young friend, a native of Bern, whose name, Jean Steiger, well deserves a record. In the pursuit of knowledge, he visited Strasburg, Paris, and Bourges, and returned to his native place to assume the duties of a schoolmaster; which occupation, however, he quitted for the practice of medicine. He subsequently became professor of Greek at the university of Lausanne, obtained the degree of doctor of medicine at Bâle, and continued to practise as a physician at Zurich, pursuing his scientific labours in conjunction with the exercise of his profession. Having devoted his attention to patients attacked with the plague, which then unhappily prevailed, he perceived the symptoms of the malady on his own person, and feeling the attack to be mortal, repaired to his cabinet to arrange his papers, and calmly to await, like a philosopher, the approach of death, which occurred on the fifth day of the malady, in the prime of his life and powers, in the forty-ninth year of his age. The pursuits of Gessner were of the most varied and dissimilar kinds, and his eminence undisputed in all. His favourite studies were philology and literary history, together with the theory and practice of medicine, associated with the physical sciences as far as they were then known, comprising the study of botany, fossils, minerals, and geology. He was equally skilled in the arts, and drew the illustrations for his various

works with a fidelity and skill which have frequently been acknowledged and admired. His most important literary production is his *Bibliotheca Universalis*, or catalogue of all known authors in Latin, Greek, and Hebrew, a work of immense learning and labour; as well as his *Mithridates*, a philological performance, in which we find the Lord's Prayer in the twenty-two languages with which, like the monarch after whom his treatise is entitled, he was acquainted. He farther edited a great number of classic authors, and we owe to him the first translation of Ælian. His most valued performance in natural history is his *Historia Animalium*, which may be regarded as the foundation of modern zoology; while, as a botanist, he was the first to arrange plants in the order of classes, genera, and species, and thus to raise this study to a system. His work *De Rebus Fossilibus* contains figures of many fossils well represented: he does not appear to have decided whether these objects were the remains of living beings, or were produced by natural forces; opinions which divided the savans of Europe for more than a century after his death. His personal character was as amiable as his philosophical attainments were eminent; pious and pure, gentle and unassuming, he was equally admired and beloved.

Bernard Palissy, born in the diocese of Agen, in France, in 1499, was among the first who maintained that fossil shells found in rocks were the remains of marine animals; he argued from the state of preservation in which they were discovered, with their most delicate spines and processes preserved, that they could not have been transported from a distance by an inundation of water, but must have lived and died on the spot where they were found.

This idea formed the germ of the great truths which subsequent discoveries have more fully unfolded. Palæontology, thus born on the soil of France, has ever been most largely indebted for its advancement to her distinguished philosophers. It is, also, to Palissy that agriculture is indebted for the discovery of the use of marl as a mineral manure.

The progress of natural history in Italy may be estimated from the taste which arose towards the close of the sixteenth century, for forming and describing collections. The richest then existing in Italy, as we are informed by Brocchi, was

that of the Vatican, formed under Pope Sixtus V., and arranged, described, and figured by Mercati, whose amount of philosophic knowledge may, however, be estimated by the fact, that he attributed fossils to the agency of the celestial bodies. The collection of the Vatican was dispersed soon after the death of Mercati; but others were formed at Verona, Naples, Milan, Bologna, and other cities of Italy, which soon led the way to more correct opinions. Thus Cesalpini, the botanist, (1596,) may be mentioned as one among the earliest who determined the real nature of fossils, ascribing them, in distinct terms, to "the retiring of the sea and the lapidification of the soil." Fabio Colonna, another botanist of eminence, (1626,) achieved a still farther progress, and showed not only the reality of the shells, but arranges them according to distinct genera and species, proving that some were referable to marine, others to fresh-water kinds, and that the teeth found with the marine species were not those of serpents, as had been supposed, but of sharks. He farther pointed out the difference between the petrified shell, the impression, and the cast which the decomposition of the shell left in the substance which it has inclosed. Steno, as he is called by the Italians, but whose name in his native tongue is Nicolaus Stenon, a native of Copenhagen, naturalised in Italy, who flourished about the middle of the seventeenth century, was an able anatomist and physiologist, one of the earliest who observed and described, with accuracy, the muscular and nervous systems, and the structure and functions of the brain. He alike directed his inquiries to mineralogy and geology. His work, *De Solido intra Solidum contento*, displayed many sound and philosophic principles, mingled with several of the prevailing errors of the time, and, in deference to existing prejudices, were rather submitted as propositions than affirmed as facts. He was one of the first to make known the fossil bones found in such great abundance in the Val d'Arno, in Tuscany. He contended for the vital origin of fossil remains, but considered that they might have been produced by the Noachian deluge. He farther asserted that fossil vegetables are the remains of once living plants, and that the mountains are of secondary origin, formed since the creation of the earth. He was a man of a very powerful

and gifted mind, highly improved by careful study and cultivation, and would, doubtless, have effected much more for science, had not his attention been called away to other objects.

Scilla, a Sicilian painter, published, in 1670, a work on the fossils of Calabria, in which he vindicated the vital origin of these objects, ascribing them to the agency of the deluge. Quirini, (1690,) in a work descriptive of fossil shells, expresses opinions far more advanced: he maintains that petrified shells cannot have originated from the deluge recorded by Moses; intimates that the Scriptural relation of this event is not to be subjected to a strictly literal interpretation, and suggests, among other propositions, the idea that the visitation in question was by no means universal in its prevalence. In support of these positions, he denies that bodies of such considerable weight could possibly have been floated to the summits of lofty mountains, or that the agitation of the waves could have produced such a result; citing the statement of Boyle, then recently published, that the most furious storms affect the sea only to a moderate depth. He is still less inclined to the doctrine of the shells having grown in the waters of the deluge, on account of the brief duration of that event, and the fact that the excessive rains must have deprived the sea of its saltness.

Vallisneri (1721) was distinguished for the philosophic freedom of his doctrines, contending against the universality of the deluge, and its adequacy to account for the existence of fossils. Moro (1740) advocated the efficacy of igneous causes, and demonstrated the elevation of mountains, and the occurrence of other phenomena, to have been caused by their agency; while at the same time he strenuously contended for the literal interpretation of the six days recorded in the Mosaic account as the period of creation, commencing first with the prevalence of water, and next of animals and plants. His system bears a resemblance to that subsequently promulgated by Hutton, for which it may have furnished some ideas. Sir C. Lyell has observed, that as, from the prolixity of his style and the novelty of his views, he required an expositor, the Scottish philosopher was not more fortunate in the advocacy of Professor Playfair, than was Moro in that of his admirer Generelli, who, nine years after, delivered to the

assembled Academicians of Cremona a spirited exposition of his theory. It may be stated as a farther and singular coincidence, that as we owe to Professor Playfair, in later times, the idea of a destructive and conservative power in nature, which form a counterbalance to each other; Generelli concludes with enforcing the same principle, and contends that Providence has constantly raised from the deep fresh mountains to supply the disintegration of others,—a fact, he adds, which satisfactorily accounts for the number of crustacea and other marine objects now found in many mountains.

MARSILLI (1740) pointed out the very important truth that fossil shells are not distributed at random, but in certain associations of genera,—a fact which, somewhat later (1750), was more fully established by DONATI. TARGIONI (1754) proved that the elephants whose remains were abundantly discovered in various parts of Italy, once existed on the strata from which their relics are exhumed; while ARDUINO (1759) made the important advance of classifying the rocks into primary, secondary, and tertiary deposits.

BALDASARI (1767), in a memoir on a fossil jaw-bone (that of a mastodon), enters into many philosophical speculations, and establishes several important principles of geology. One is, that the sea has certainly had a permanent abode on our continents,—a doctrine which he founds on the three convincing facts, the regular distribution of marine objects in the strata of mountains, the natural position presented by corals and other zoophytes, and the circumstance that the calcareous strata are perforated by *Pholades*. He inculcated, almost in the same words, the excellent principle adopted by the early members of the Geological Society, to collect materials before forming systems; and states that it is with this view that he calls attention to the fossil jaw in question, which was procured from Monte Pullonico, in the territory of Sienna, and which he correctly refers to those described by Guettard, as having been discovered in America and India, and which are now recognised as those of the mastodon.

SOLDANI (1789) is celebrated for the comprehensive nature of his inquiries, and the philosophic accuracy of his decisions. While he devoted especial attention to microscopic investigation, and published a splendid work on

minute zoophytes and shells, he formed the most enlarged views of nature, devoting his attention to the structure of the earth, the action of water, the formation of mountains, and the composition of rocks. It may be cited as his highest eulogium, that he was too much in advance of his contemporaries to be esteemed or appreciated by them. His great work* was so coldly received by the public, that he was about to commit to the flames the greater part of the manuscript of the second volume, and actually consigned to the brazier the whole of the copperplates. But his writings, scarcely appreciated at home, were prized and studied abroad,—in Germany by Fischer and by Moll, and in France by Montfort; while his countryman, Professor Ricca, called attention to his merits, and pronounced a public eulogy on him some years after his decease. Brocchi adds, that he is, even now, scarcely honoured in proportion to his deserts, and in particular, that having been the first to call attention to the occurrence, in various parts of Italy, of fresh-water deposits among those of a marine origin, and the first to point out the alternation of marine and fresh-water strata in Xaris' basin, his admirable observations have been passed over in silence by later writers, to whom, however, they could not have been unknown.

The history of geological inquiry during the sixteenth and seventeenth centuries consisted chiefly of a series of contests on the questions of the organic nature of fossil objects, and their deposition by the deluge; a compromise being usually effected, naturalists conceding what they considered the minor point, the universality and power of the flood, in order to secure the more important admission, the animal origin of fossil remains. Towards the close of this period, Leibnitz, in his *Protogæa*, published those views of the original incandescence of our planet, and its subsequent refrigeration, which later inquiries have tended so largely to confirm. Another distinguished mathematician of the same era, Dr. Hooke, promulgated, in his writings, similarly just and enlightened views of the organic nature of fossils,—the extinction of species,—the former tropical climate of the earth,—the effects of volcanic action, subterranean and sub-

* Testaceographia ac Zoophytographia parva et microscopia, 3 vols. fol. 1789—1791.

marine,—the elevation and depression of the land, &c. &c. The celebrated naturalist, Ray, had already lent the weight of his character and attainments to this new but progressive study; and Dr. Woodward subsequently farther promoted its cultivation by bequeathing his collection to the University of Cambridge, and endowing a professorship of the science. The naturalists of Italy, already mentioned, Vallisneri, Moro, Generelli, Donati, Targioni, and others, prosecuted their inquiries with energy and success, and Linnæus directed his investigations to the structure of the earth. He contended against the universality of the deluge; arranged the different formations in a natural order of succession; showed that the calcareous deposits are of vital origin, composed of zoophytes and shells, and proved that animal as well as vegetable remains have contributed to make up the solid crust of the earth. Buffon's *Des Epoques de la Nature* largely promoted the advancement of geology. The illustrious zoologist's magical pen portrayed with all the brilliancy of graphic description, the changes that have taken place in the earth's crust during the epochs of its past history. The countrymen of Leibnitz successfully prosecuted the same inquiries; and, in the year 1759, Lehman, director of the Prussian mines, a skilful mineralogist and chemist, published a work, in which he classified the rocks into primary, secondary, and tertiary, in the same year that Arduino proposed a similar arrangement.

EMANUEL SWEDENBORG (1720), in the early part of his career, acquired considerable proficiency in the physical sciences, traces of which are discernible in his later writings. His publication entitled *Opera Philosophica et Mineralogica*, in three volumes folio, with numerous engravings, was justly regarded as a most extraordinary performance. His scientific observations contain some sound principles and instructive facts; the nebular theory of the solar system, the original fluidity of our planet, and its various preparatory changes, as opposed to the prevailing idea of its instantaneous creation in its present matured condition; the succession of various tribes of animals and plants; these, with other assertions, the truth and accuracy of which have been demonstrated by modern science, are the lights which shine through the mystical philosophy which pervades his works.

WERNER, who succeeded to the professorship of mineralogy at Freyberg, in Saxony, in 1775, directed his views from that science to geology, and the general structure of the earth; and, by his genius and eloquence, obtained for a lengthened period universal favour and popularity. As the summary of his system, it may be stated, that water was considered the universal agent in the formation of rocks, which from the granite up to the most recent beds, were regarded as aqueous deposits; while volcanoes, which constitute so important a cause in their production, were conceived to be merely of recent date, and to have been quite unknown and inoperative in the ancient history of the earth. From the universal agency thus ascribed to water, his followers were termed Neptunists; while their opponents, who advocated the igneous origin of many rocks, and maintained the action of fire, were termed Vulcanists.

The faults of Werner and his system, the dogmas of the universal operation of water, and the utter exclusion of an agent so obvious as fire, have long since been exploded. His errors, both of theory and practice, are to be ascribed to the position of the man, and the prejudices which that position induced. As a mineralogist, he was led by his peculiar bias for classification, to apply a strict and contracted method of arangement to phenomena, too vast and varied for so narrow a limitation; and, in practice, he formed his conclusions as to the structure of the whole earth, from the partial investigation of a single district. Hence, his system has met with the fate of all those which form extensive generalisations on few and insufficient data, and which attempt to explain the vast operations of nature from observations of local extent and limited influence. He formed a world on the model of the valleys of Saxony, rejected the possibility of igneous rocks, when the inspection of the trap-dikes in the Hartz mountains would have convinced him of their reality; and denied the existence of ancient volcanoes, when a journey to Auvergne would have satisfied him of their existence. He was, however, a man of a very high order of mind, gifted with genius, energy, and eloquence; while, as a mineralogist, he was eminently acute and skilled in the power of classification and arrangement, as well as in determining the order and succession of local deposits. His errors have served

as a guide to later observers, who, warned by his example, first seek sufficient data before they presume to propose a theory, and visit the scene of inquiry ere they attempt to form a judgment as to the phenomena which it presents.

Meanwhile DE SAUSSURE and PALLAS had arrived at similar conclusions, by means of independent researches; the one by the exploration of Switzerland and the Alps, and the other by that of Siberia and the Ural mountains, both recognising the existence of internal heat, and its operation in raising portions of the earth's surface into mountains.

DR. TOULMIN's Essay on the Antiquity of the World was published about the year 1775, and affords an interesting example of the progress of opinion: sentiments which little more than half a century ago drew on their author the opprobrium of being a sceptic, are now admitted as demonstrable truths. He maintains that *no single substance in nature is either permanent or primary;* that the animals, the vegetables, the earths, the stones, the minerals alike take their origin in the gradual progress of time, and in its increasing succession are alike exposed to innumerable transmutations; that the globe itself, from a multitude of causes, is subject to slow, but important revolutions; that it undergoes incredible changes from heat and cold, volcanoes and earthquakes; that vast alterations are gradually made by the decay, generation, petrifaction, and other transmutations of vegetables and animals; that the sea is continually altering the surface of the earth; that in the lapse of time, it encroaches on the dry land, and takes it from its inhabitants, and restores it to them again; and that gradual influences occasion those numerous, but partial inundations which have been found to make such deep and lasting impressions, and have existed in every country, leaving behind them the most visible marks of ruin and devastation. The conclusion of the author is, that *nature is invariably the same—her laws immutable and eternal.*

The above remarks convey the substance of the systems of later philosophers. The first passage, which we have distinguished by italics, contains the essence of the theory of Dr. Hutton; the second embodies some of the leading principles which, recently enforced by Sir C. Lyell, were, at an earlier period, advocated by Dr. Hutton and Professor

Playfair. "Amid all the revolutions of the globe," observes the latter, "the economy of nature has been uniform, and her laws are the only things that have resisted the general movement. The rivers and rocks, the seas and the continents, have been changed in all their parts, but the laws which direct these changes, and the rules to which they are subject, have remained invariably the same."*

The most distinguished opponent of Werner in this country, was Dr. Hutton, a Scottish physician, whose opinions, on all essential points, were the very reverse of those of the professor of Freyberg.

As the substance of his theory, which has been designated the Plutonian, he taught the following important truths:—

First, that no geological phenomena afford any proof of the beginning of things.

Secondly, that the oldest rocks are merely derivative compounds of the ruins of rocks which existed before them, and which were destroyed, chiefly by the slow action of atmospheric causes; while their detritus, borne by rivers to the ocean, and loosely strewed over its bed, became consolidated by heat, and subsequently upheaved and fractured.

Thirdly, that the metamorphic rocks were originally sedimentary deposits, similar to the secondary, but that they have been altered by the long-continued action of heat.

Fourthly, that granite has crystallised from a state of igneous fusion, under conditions of heat and pressure. In other words, that it has been melted by fire, at great depths in the earth, and has cooled under pressure so vast as to have prevented the gaseous portions of its elements from escaping, and has thus assumed its present crystalline texture.

Such is an outline of the celebrated system of Dr. Hutton, which has not only supplanted that of Werner, but has formed the foundation of the researches and writings of our most enlightened observers, and is justly regarded as the basis of all sound geology at the present day.

If we examine the above propositions in detail, we shall only find them to have been confirmed by repeated investigation. The crystalline texture and igneous origin of granite

* Illustrations of the Huttonian Theory, § 37.

admit of neither doubt nor dispute; the metamorphic character of the succeeding deposits, the gneiss and mica-schist systems is equally clear, whether we suppose with Sir C. Lyell, that the metamorphism was complete, or with Professor Phillips,* that it was only partial. The derivative character of the sedimentary strata is fully proved; and the whole of these propositions are only better understood, and more firmly established, after having stood the test of half a century of investigation.

The most important and novel of the whole, the altered character of the metamorphic rocks, has been demonstrated by Sir James Hall's experiments, who, by pulverising chalk and hermetically sealing it, so as to prevent its gases from escaping, and then exposing it to heat, converted it into crystalline marble; the very result presumed to have occurred in nature, by the hypothesis of Dr. Hutton. In a practical point of view, the fluid nature of granite was considered to be proved by the investigations of the author himself, who discovered in Glen Tilt veins of granite, ramifying into superincumbent rocks, in a manner which could only have been effected by a substance in a melted state, a discovery which is said to have filled him with so much delight, that his guides, says his biographer, conceived that he must have discovered a mine of gold. His opinions are farther conceived to be demonstrated by the passage of these rocks into each other; by the graduation of plutonic into metamorphic deposits, and of the latter into others of decidedly aqueous origin; of granite into gneiss, and of chlorite-schist and mica-schist into clay-slate, a fact demonstrating the intimate relation of each, and the common origin of all; proving them to be what he declared them, sedimentary deposits, altered by heat under pressure.

Another individual, who has already been mentioned in these pages, unassisted by the advantages of wealth, station, or collegiate education, was laying down the basis of English geology, by a series of the most laborious and practical observations. WILLIAM SMITH, a surveyor, by dint of unwearied observation, and the natural powers of a strong mind, had arrived at results similar to those obtained about the same

* See his Treatise on Geology, in Lardner's Cyclopædia, vol. i. p. 109.

time by the most distinguished continental geologists, on the law of superposition of the stratified rocks; having discovered that the order of succession of the different groups was never inverted, and that they might be identified at very distant localities by their characteristic fossils. From the period of publishing his Tabular View of the Strata, in 1790, he continued his labours, under every difficulty and discouragement. Unaided, unpatronised, almost unnoticed and unknown, he pursued, alone, and on foot, a series of investigations, which terminated in the publication, in 1815, of his Geological Map of England—a lasting monument of his genius, industry, and unwearied perseverance; and to which D'Aubuisson, a distinguished pupil of Werner, paid a just tribute of praise, observing, that "what many celebrated mineralogists had only accomplished for a small part of Germany, during half a century, had been effected by a single individual for the whole of England."

The remaining events which mark the history of the science, as regards this country, may be comprised in a brief epitome. The casual assembling of some friends for the transaction of business of scientific import, occasioned the wish for the continuance of meetings which were found to be as instructive as they were delightful, and gave rise to the GEOLOGICAL SOCIETY; an event which, more than any other, has promoted the advance of the science. Warned, by example, of the danger of hasty generalisations, its members wisely abstained, for a considerable period, from all attempts of this nature; and Sir C. Lyell has recorded the intention and the eulogy of the society in the same sentence, by declaring the object of its supporters to have been to multiply and record observations, and patiently to await the result at some future period; while their favourite maxim was, that the time had not yet arrived for a general system of geology, but that all must be content, for many years, to be exclusively engaged in furnishing materials for future generalisations. A resolution so judicious could not fail to produce the most satisfactory results, and the natural consequence has been, not merely to rescue geology from the distrust which once attached to it, but to render it the favourite, as it unquestionably is one of the most fascinating, of the natural sciences.

Similar societies were formed in the capitals and provinces of the British empire, and of France, Germany, and Belgium. Some years ago, the *savans* of Germany conceived the idea of holding annual meetings, for the purpose of scientific investigation, and under the unassuming title of *Naturforscher*, of meeting and communicating the result of their researches during the past year. The British Association was instituted for a similar purpose; among its objects geological investigation has formed a principal feature; a considerable portion of its funds has been devoted to the assistance, not only of British, but of foreign inquirers, and the general interests of science have been advanced by its aid.

We have purposely omitted to dwell on the labours of French philosophers in the same field, because the discoveries and writings of Cuvier, Brongniart, Elie de Beaumont, Dufresnoy, D'Orbigny, Archiac, and their associates, will form the subject of frequent and honourable mention in the course of the following pages.

To bring the history of the science down to the present moment, it may be necessary to advert both to the *acta* and *agenda* of its inquiries, and to mention both those problems which are supposed to be solved, and those which yet remain for determination. Among the former may be regarded the raising of the group of rocks, named old red sandstone, into the rank of a separate series. For a considerable period doubts had been entertained as to whether the red sandstone of Devonshire was identical with that of Herefordshire; the discrepancy between the two consisting chiefly in the fact, that the shells discovered in Devonshire are not found in Herefordshire, nor the fish of Hereford in the county of Devon. Sir R. Murchison, in his recent journey to Russia, discovered both fish and shells in the same deposits; and the old red sandstone of Devon, Hereford, and Scotland, is now constituted a distinct group, under the title of Devonian.

The discovery of new forms of reptiles, has widely extended the frontier line of those types of animal life, and proved the age of reptiles to be a period which extended from the trias to the chalk; in other terms, through the vast cycles of ages, during which the whole of the secondary rocks were deposited.

Mr. Hopkins has recently applied, in a highly successful manner, the principles of mathematical investigation to the explanation of geological phenomena, particularly with reference to the dynamics of the science, the elevation of entire tracts of country, the prevalence of anticlinal lines, and the nature of transverse fissures, and fractures occurring at right angles to the central rise. He has thus brought a powerful auxiliary into the field of geological research, and has supplied a new link between mathematical and natural science.

The discovery of erect trees in the coal-formation, particularly of six splendid specimens found by Mr. Hawkshaw, on the line of the Bolton and Manchester Railway, together with the researches of Mr. Bowman, Mr. Logan, and others, has tended to modify, to a considerable extent, the opinions previously entertained as to the mode in which coal was deposited; and whereas it was formerly believed to have been generally distributed by drift, and but occasionally to have vegetated on the spot where it is now discovered, the reverse of this sentiment seems now to prevail, and the greater part of the coal is believed to have grown on or near the spot where it is now found, while the instances of drift, at all events, to any remote distance, are conceived to form the exception to this rule. Certain coal-plants, the *Sigillariæ*, which have hitherto been regarded as monocotyledonous, are now, with more probability, considered to be dicotyledonous: and as the genus is numerous, such an alteration would change, to a considerable extent, the relative proportion of the two orders of plants of this formation.

It may be added among the most recent advances in geological inquiry, that Sir R. Murchison having some time since stated it to be his opinion that the Silurian deposits are the oldest fossiliferous rocks, recent researches have tended strongly to confirm this view, and to show that both the Cambrian and Cumbrian systems, which lie beneath, present so close an analogy, in many important points, with the Silurian, as to render it highly probable that the whole will hereafter be regarded as one common series, that of the protozoic or earliest rocks which contain organic remains.

Erratic Blocks.—With reference to these phenomena, the large boulders and masses of primary rocks, which are found scattered over the superficial soil, in every country of

the north of Europe, the weight of evidence unquestionably is in favour of the supposition, that they have been transported by masses of floating ice, which, on melting, dropped these blocks in the then existing sea. On this point, among other proofs, the evidence of M. Durocher, now professor at Rennes, in Brittany, who has attentively studied these boulders as they occur in the north of Europe, may be regarded as conclusive. His opinions are in substance as follow:—As the direction of the blocks is usually from north north-west, to south south-east, he conceives that in the first instance some powerful erosive agency has disintegrated and destroyed the mountains of the north, reducing their masses to blocks, which have accumulated at their basis on the coasts then in existence, while, at the same time, the rivers and streams have tranquilly conveyed the smaller detritus into the sea. During intense winters, masses of ice have embedded and floated away these blocks; and such icebergs, on melting, have deposited the blocks in various directions. The elevation of the bed of the sea has subsequently brought them to light. For some interesting observations on the glacial furrows observed in the valley of the St. Lawrence, and the action of packed ice in the Canadian rivers, the reader is referred to Sir Charles Lyell's travels in North America,* First Series. "About three miles south of Halifax, near 'the Tower,' I observed," says this distinguished observer, "a smooth surface of rock, formed of the edges of curved and highly inclined strata of clay-slate, crossed by furrows about a quarter of an inch deep, having a north and south direction, and preserving their parallelism throughout a space of one hundred yards in breadth. Similar phenomena are observed in other parts of this peninsula. On the removal of the drift, I observed a polished surface of quartzose grit of the coal measures with district furrows running E. and W. or E. 15° N. magnetic." †

The Glacial Theory.—Among the *agenda* of the science, or the questions yet to be proved, may be reckoned the glacial theory of M. Agassiz. This philosopher, having followed out the researches of Venetz, Charpentier, and

* Vol. i. p. 163.

† For much interesting information on "Glacial Scratches," see Lake Superior, its Physical Character, &c., by Professor Agassiz.

others, and having arrived at the conclusion, that the glaciers of the Swiss Alps had formerly a greater extension, and reached as far as Mount Jura, determined to investigate the traces of glaciers in England, Scotland, and Ireland. The existence at a former period of glaciers of far greater importance and extent than those with which we are now acquainted, covering, in fact, the whole of Switzerland, and presenting an area of sixty leagues, with a surface of more than two hundred square leagues, seems to have been completely and satisfactorily established by the researches of M. Charpentier, whose testimony is of the more value, because having at first been opposed to the theory, he became, by the result of his inquiries, a convert. But though the certainty of these vast fields of ice, in Switzerland and its vicinity, seems to be thus demonstrated in a convincing manner, it is by no means so clear that the same phenomena existed in other and distant regions, and even if they did, it is not considered that they account for the erratic blocks, which we have already referred to another cause. M. Agassiz conceives that the markings and striations of the rocks observed in Great Britain, are similar to those occurring in Switzerland, and testify the former prevalence of extensive glaciers in these regions. He farther applies their agency in explanation of many local phenomena; in particular, of the erratic blocks, and of the parallel roads of Glenroy, which are certain level terraces on the sides of mountains, previously supposed to be ancient sea-beaches left by the retiring of the sea. His views have been warmly espoused by Dr. Buckland and Sir C. Lyell, but have met with much opposition in Germany,* It must be admitted that they scarcely account in a satisfactory manner for all the phenomena which they are adduced to explain, in particular the parallel roads above-mentioned; Sir R. Murchison, on his recent visit to Russia, found them insufficient to explain the position of the erratic blocks strewed over vast portions of that country.† The late Mr. Bowman stated‡ the following objections to the

* Particularly from Studer and Von Leonhard. See the admirable work of the latter, *Geologie oder Naturgeschichte der Erde, auf Allgemeine fassliche Weise abgehandelt*, p. 487, Stuttgart, 1840.

† See Proceedings of the Geological Society, vol. iii. p. 405.

‡ Philosophical Magazine.

conclusions formed in favour of the theory from the striated markings presented by the surface of the rocks. He found these marks to pervade the internal structure as well as the surface; and as they occur parallel to the plane of the magnetic meridian, he ascribes them to electro-magnetic agency, operating during the induration of the mass. Mr. Hopkins denounces the theory as contrary to every principle of physics, in relation to the phenomena of several districts to which he has directed his researches; and finally, Dr. Buckland, in his Anniversary Address (1841), intimates that the opinions of Professor Agassiz and himself as the supporters, and those of the opponents of the theory, "will probably be settled, as in most cases of extreme opinions and exclusive theories, by a compromise; the glacialist will probably abandon his universal covering of ice and snow, and be content with glaciers on the elevated regions of more southern latitudes than now allow of their formation; the diluvialist, still retaining his floating icebergs as the most efficient agents in the transport of drift and erratic blocks to regions distant from their place of origin, may also allow to glaciers their due share in the formation of *moraines* and striated surfaces, in latitudes and at elevations that are no longer within the zones of perpetual congelation."

EXERCISES.

The history of a science affords little opportunity for exercises of a practical nature, while the brevity of our sketch renders recapitulation scarcely necessary.

The student may, however, transfer to his note-book, and otherwise impress on his memory, a few of the most important facts.

1. In perusing the history of the science he will observe, that the most philosophic minds are usually in the right, in opposition to the multitude; while some gifted observer progresses in advance of his own and succeeding ages. Thus, Aristotle and Strabo had formed far more just ideas of the phenomena of nature than were entertained by their contemporaries; Pythagoras, or rather the author of the system advocated as his, in the passage which we have cited from Ovid, observed many facts of importance, and rightly understood their nature. The opinions of Boccaccio and Leonardo da Vinci were in advance of their age, as were those of Leibnitz, Linnæus, Toulmin, and Hutton.

2. The following may be regarded as the summary of the history of the science in modern times:—In the darker ages fossil remains were ascribed to the stars, or to some plastic power of the earth itself, or were regarded as mere *lusus naturæ;* in fact, their origin was referred to every cause but that which was alone capable of producing them. It was only after long and arduous contests that naturalists succeeded in establishing the organic nature of fossils; and this point could only be gained by conceding the universality of the deluge, and ascribing their occurrence to that event. It soon became evident that such a cause was inadequate to explain all the conditions under which these objects occurred: that though it might have strewn them over the surface, it never could have buried them in the strata of

mountains, or entombed them deep within the earth itself Again: it was observed that marine shells were associated in one spot, and the fresh-water kinds in another, and that similar genera and species were in like manner separated and arranged, although it was obvious that the flood here contemplated must have heaped all kinds promiscuously together. And, when at length more extensive observation showed that the same locality exhibited alternations of marine and fresh-water deposits—it was felt that no single event was adequate to produce such varied effects; and hence arose the more extended views of the operations of nature which constitute the principles of modern geology.

CHAPTER III.

First Lessons in Geology—Harmony of the Science with Revelation—Extreme Antiquity of the Earth—Proofs of this fact derived from the Structure of the Earth itself—Similar Evidence afforded by Astronomy—Origin of our Planet—Internal Heat of the Earth—Crust of the Earth—Order and Succession of the Rocks—Tropical Climate of the Ancient Earth—Efficacy of Modern Causes.

We shall take this opportunity, before entering on the more practical portion of our subject, of stating some of those leading principles which serve as an introduction to the science, and tend to facilitate the future progress of the student: these we shall term—First Lessons in Geology.

Harmony of the Science with Revelation.—Among the most valuable and satisfactory of these may be enumerated the conviction of the perfect harmony of the science with revelation, and the groundless nature of those fears which many well-meaning persons entertain of the possibility of a collision between them. It may be sufficient to state, that, in all essential points, the records of Scripture are completely confirmed by the evidence of physical fact. This admirable study, so far from lessening our belief in the Deity, or our perception of His attributes, tends materially to enhance and confirm our appreciation of both. A science, which extends our knowledge of creation, exalts, in a commensurate degree, our admiration of the Creator. Those who would pursue the subject farther are referred to the works of Lyell, Buckland, Delabeche, Murchison, Sedgwick, the various works of Mantell,* and Dr. Pye Smith, all of which furnish arguments so powerful and convincing, that they cannot fail to remove the apprehensions of the most sensitive mind.

* Wonders of Geology, 2 vols., 18*s.*; Medals of Creation, 2 vols., 21*s.*; Geology of the Isle of Wight, 12*s.*; Pictorial Atlas of Fossil Remains, 4to, seventy-five coloured plates, 45*s.*

INSTRUCTIVE NATURE OF THE SCIENCE.—Geology has this in common with the other studies of nature, that it shows us the error of many of our early impressions, and warns us to doubt the evidence of our senses, until proved by scientific investigation. Thus, while Astronomy convinces us that the sun, which rises in the east and sets in the west, makes no revolution at all, but that it is the apparently unmoving earth which really performs the daily round; so Geology commences her instructions with truths not less at variance with our preconceived opinions. It unfolds the fact, that the present condition of our earth, far from being of primeval date and character, constitutes but one of the numerous vicissitudes through which it has passed in the course of its eventful history. The mountains which we deem of antiquity coeval with the earth itself, the hills which in our phraseology are "old," to a proverb, this science convinces us are of very different dates, and have all, geologically speaking, been elevated at comparatively modern periods. Again, from the earliest times it has been the habit of man to associate the idea of stability with the land, and of fluctuation and change of level with the sea. Geology, however, demonstrates the very reverse of this to be true, and shows that while the land has undergone changes and disturbances, and has been the scene of elevation and depression, of intrusion and dislocation, the sea, from its nature, as a fluid, has constantly maintained the same unaltered level. The rocks, which we regard as having ever been the hard, and unyielding objects which we behold them now, by the external characters which they bear, by the gentle impressions of organic structure which they present —by the tender foliage of the plant—the delicate markings of the shell—science proves to have been thus imprinted when their substance was soft, and by this means convinces us that rocks were once in a state of sand or mud. These are but a few of the instances which might be adduced of the valuable and instructive discipline of a science which rids us of errors and prejudices derived from early habit and association, and implants in their stead more just and philosophical ideas of nature, and her Divine Author.

ANTIQUITY OF THE EARTH.—Thus while we are accustomed to regard our planet as coeval with man, and as

dating but from the five or six thousand years which science and revelation unite to prove as the era of his creation, Geology demonstrates the far higher antiquity of the planet assigned for his abode. A mere investigation into the crust of the earth, will convince us that the substances of which it is composed, from their variety, extent, and order of succession, could only be the result of accumulations continued through vast cycles of time. The series of the fossiliferous formations are the mineralised beds of primeval oceans, with occasional intercalations of fluviatile and lacustrine strata; the deposits of seas, or of rivers and lakes, bearing, in their stratified arrangement and the relics of the animal forms which once inhabited their waters, incontestable proofs of their sedimentary origin. These aqueous accumulations, subsequently to their deposition, have repeatedly undergone the action of disturbing causes; the eruptive rocks have broken through the sedimentary deposits, and volcanoes, terrestrial and submarine, have exploded from below, shattering the superincumbent beds, and wedging their sheets of molten matter into the chasms of the strata they have divided, or, bursting to the top, have poured their waves and spread their terraces over the surface of the whole. Periods of intense volcanic activity have been followed by others of repose, which have again been succeeded by revivals of former energy; so that frequent alternations of this nature, of enormous extent and duration, have occurred, even in periods which are regarded as comparatively recent in the history of the earth.

The question of geological time is one of much difficulty. It has, however, received important illustration from the recent investigations made by Sir Charles Lyell, relating to the eroding power of the celebrated Falls of Niagara.

It has long been a popular belief that the Niagara flowed in a shallow valley across the whole platform from the present site of the Falls to Queenston Heights, where it is supposed the cataract was first situated, and that the river has been slowly eating its way backwards through the rocks which belong to the Silurian series, for a distance of seven miles. The strata throughout the whole region are nearly horizontal, having a gentle dip to the south of twenty-five feet in a mile.

It has been ascertained that the Falls have shifted their

position during the last half-century, and the small portion of the great ravine which has been eroded within the memory of man is so precisely identical in physical and geological character with the whole gorge of seven miles below, that the river supplies an adequate cause for executing the assigned task, provided we grant sufficient time for its completion.

The water, after cutting through strata of limestone, fifty feet thick, in the rapids, descends perpendicularly at the Falls over another mass of limestone ninety feet thick, beneath which lie soft shales of equal thickness. The disintegration of the shales causes masses of the incumbent limestone rock to fall down, and thus the cataract recedes southwards.

By the erosion of the shales and limestone by the water, the conditions being uniform, we are enabled to infer, from what has taken place within a known time, the probable period which this seven miles required for its accomplishment.

Sir C. Lyell has found proofs that the river extended four miles north of the Falls, having discovered beds of gravel reposing on the cliffs overlying the ravine, containing fluviatile shells resting on the limestone, of the same species as those now living in the adjoining water.

Mr. Bakewell estimated the rate of erosion for forty years before 1830 to be about a yard annually. Sir C. Lyell states that one foot would be a much more probable conjecture; in which case, thirty-five thousand years would have been required from the retreat of the Falls from the escarpment of Queenston to their present site, if we could assume that the retrograde movement had been uniform throughout. "This, however, could not have been the case; as at every step in the process of excavation, the height of the precipice, the hardness of the materials at its base, and the quantity of fallen matter to be removed, must have varied. At some points it may have receded much faster than at present, at others much slower; and it would be scarcely possible to decide whether its average progress has been more or less rapid than now." *

In pursuing the natural and legitimate mode of interpreting the past by the present, and observing the effect of similar

* Travels in North America, vol. i. chap. 2.

agencies in existing nature, we are forcibly impressed with the slowness of these operations at the present day. Lakes are ascertained to shoal up, in the proportion of only a foot in a century; and oceanic deposits are known to be correspondingly tardy of accumulation. Hence we find that during the entire historic period, the physical geography of our globe, with the exception of local and minor modifications, has remained unaltered. The oceans, rivers, lakes, and mountains recorded in Scripture, form the physical features of the same regions at the present day; the ocean which Cæsar crossed, still separates the Briton from the Gaul; the same rivers water the capitals of the same countries of Europe; while the same Vesuvius which overwhelmed Herculaneum and Pompeii still threatens the surrounding districts; and the same submarine volcanic agency which alarmed the Roman people, continues in activity, and produces similar phenomena at the present day.

When we contemplate those operations which have formed or modified the crust of our globe, and observe their extent and grandeur; when we find evidence, not of a single change, but of cycles of changes; of seas on seas; with alternations of dry land in the existence of forests, rivers, and lakes; together with proofs of volcanic agency, with its long-continued intervals of action and repose; and when we reflect that nothing is made in vain, but that every created object has its sphere of usefulness, and therefore of duration; and when we look on the fair and harmonious world around us, and examine the diversified materials of which it is composed, and the wondrous agencies by which it has been elaborated into order, fertility, and beauty, we cannot avoid the conviction, that operations thus complicated and extensive, and results thus admirable and perfect, must have required an adequate period for their development; and that time, to an extent inappreciable by human powers of calculation, must have formed an essential element in the vast work of Creation.

Antiquity of the Universe proved by Astronomy.—It is the profound remark of Lord Bacon, that we must seek the explanation of a phenomenon not merely in the investigation of that object alone, but by comparing it with others of like nature with its own; and thus the antiquity

of our earth, far from being inconsistent with the general plan of creation, is only in accordance with the enlightened views which have been formed of the universe, the magnitude and grandeur of the phenomena of which as far exceed those observable in our earth, as the whole transcends the part. If geology, therefore, appears incredible, astronomy must seem impossible; yet, owing to the exact nature of the latter science, its truths are susceptible of mathematical demonstration. The astronomer reveals facts so far surpassing our usual calculations and impressions, that the mind unaccustomed to scientific investigation, might reject them as fables, were it not that he, at the same time, foretels an eclipse to the fraction of a minute, and thus proves his system to be true. For instance, there are stars so incalculably remote from our planet, that their light would require vast cycles of ages to arrive at our earth; and as these luminaries occasionally become extinguished or invisible, it results that we may actually be gazing on the light of a star which has been lost to our sphere long before the creation of our race. Sir William Herschel, in a paper* *On the power of telescopes to penetrate into space*, informs us of the existence of bodies which can only be detected by telescopes of great power, being situated nearly twelve millions of millions of millions of miles from our earth: whence it follows, that the light by which those objects have become visible to us, must have been nearly two millions of years in its progress. And when we reflect that we can by no means assume these points, however remote, to be the limit of creation, and that if we were removed to those distant orbs, we should behold, not the end of the universe, but, as it were, only its beginning, where fresh spheres in harmonious systems still extended throughout illimitable space, we must cease all doubts, acknowledge the insufficiency of the finite to comprehend the Infinite, and cease from cavilling, to wonder and adore!

MODERN DATE OF MAN.—The comparatively modern period of the creation of man, is a fact revealed by Scripture and confirmed by science. The same internal evidence which convinces us of the antiquity of our planet, affords satisfactory proof of the modern origin of our species. The whole vast

* Dr. Pye Smith, on Geology, Philosophical Transactions, 1800, p. 368.

series of aqueous deposits are crowded with fragments of plants, corals, shells, crustacea, fish, reptiles, birds, and mammalia; but no fossil remains of man have been discovered, except in those accumulations of silt or mud, which belong to the modern era—the yesterday, as it were, in the history of the past. It is only in these accumulations that we discover the remains of even the most ancient races; that in this country we meet with the implements of our British ancestors, or the coins and weapons of their Roman invaders; that in Italy we find the Cyclopean structures and works of art of the Etruscans, while vestiges of the Pelasgi are alike discoverable in similar deposits in Greece; and in the New World, traces exist of the Tulteques, a people who were the predecessors of the Mexicans, and their superiors in knowledge. Had man existed in primeval times, his remains would have been found scattered through the varied deposits from the oldest to the most recent. No impediment exists to their conservation; his bones, composed of the same elements as those of animals, are equally capable of being kept from destruction; the same battle-field has preserved the bones of the horse and his rider; the same cavern which, in earlier eras, gave shelter to the hyena and the bear, has retained their skeletons, and alike preserved the remains of those human occupants who, at a later period, found in this retreat a refuge and a tomb. Still stronger proof of the modern origin of our species exists in the fact, that if man had been an inhabitant of the earth during its early history, his skeleton would have constituted the least of those relics which he would have bequeathed to the soil. We should have discovered his works of art, which so far transcend in duration his own ephemeral existence: we should have found his cities overwhelmed in the waters of ancient seas, or buried beneath the ejections of primeval volcanoes; his majestic pyramids sunk in the bed of early rivers; his mountain-temples, hewn on the surface of the oldest rocks: we should have encountered his bridges of granite and of iron; his palaces of limestone and of marble; the tombs which he reared over the objects of his affection; the shrines which he erected in honour of his God! But in the absence of these, in any save the most superficial deposits, we recognise the complete accordance of science with Revelation. It is

impossible to form a more magnificent conception of Infinite Wisdom than that which Geology exhibits; representing the Supreme Being as first elaborating and perfecting our earth into one sphere of blessings; erecting on a foundation of granite a vast superstructure of sandstones, limestones, clays, coal, and the varied substances known as rocks: injecting their fissures with minerals and metallic ores; then, by volcanic agency, bringing these varied deposits near the surface, and so diversifying the soil as to present every variety of condition required, for its mineral, agricultural, and economical cultivation; tempering the climate to the degree best adapted for human existence; peopling it with animals suited to the use of man, for supplying him with food, and assisting him in his labours; and finally, calling him into existence, to take possession of a world which had been prepared for his reception and enjoyment.

ORIGIN OF THE EARTH.—Though cosmogony forms no part of geology, yet we may fairly indulge a curiosity as to the origin of our planet, and seek the most probable explanation of the mystery of its creation. Our guide in this inquiry must be astronomy; we must look from the earth itself to the kindred spheres which surround it, and to that far more extensive universe of which the entire solar system constitutes but a unit. The hypothesis which is supposed to offer the most probable explanation of the origin of our earth, is termed the nebular theory; it first originated in the researches and discoveries of the late Sir William Herschel and his distinguished son, and has been confirmed by the investigations of continental astronomers, Laplace, Gauss, &c.* As a brief summary of the hypothesis it may be stated, that the observers above named were, for a lengthened period, in the habit of remarking appearances in the heavens which seemed to them sufficient to account for the origin of new worlds. They observed that every portion of universal space abounds in expansions of attenuated matter, reflective of light, which they termed *nebulæ:* these appeared of various figures, and in different states of condensation, from that of a mere shapeless film, to masses

* See Dr. Mantell's Wonders of Geology, vol. i. p. 22. Professor Nichols, works on the Structure of the Universe, &c.

of more defined outline and denser structure; thence to others which assumed a globular or spheroidal figure; thus graduating through every variety of form up to orbs of light, and suns and systems like our own. The conclusions of these distinguished observers were not founded on the changes perceptible in any individual nebula, since the duration of our whole solar system would be inadequate to elicit any change in the condition of any one of these; but were drawn from the contrast afforded by the numerous bodies of this kind diffused throughout space, which exhibit every stage of change and progression. The solar system was supposed to have been created by this agency. The sun is inferred to have been alike the centre and parent of the system; existing primarily in the shape of a diffused nebula, it is supposed in the progress of rotation and condensation to have thrown off the planets Neptune, Herschel, Saturn, Jupiter, the asteroids, Mars, the Earth, Venus, and Mercury, while the satellites are presumed to have been cast forth from their primaries.*

It will readily be perceived that this supposed gaseous origin of our planet contains within itself all the conditions requisite for its succeeding changes; it being considered that the earth has passed from a gaseous to a fluid, and thence to a solid condition, as the varied processes of rotation, refrigeration, and condensation have simultaneously proceeded; the spheroidal form which it now presents, enlarged at the equator and flattened at the poles, being precisely that which would be assumed by a fluid body rotating on its axis. When the first thin pellicle cooled, and its surface hardened, the general physical divisions of the globe are supposed to have taken place, and the varied phenomena of animal and vegetable existence to have commenced.

To the mind unaccustomed to scientific inquiry, the proposition that our globe, owes its origin to a mere cloud of vapour, may appear as strange and startling as many other

* As Lord Ross has resolved, with his monster telescope, many of the nebulæ into clusters of stars, the nebular hypothesis must be regarded only as a conjecture; it is possible that with instruments possessing greater penetrating power, the whole of the nebulæ might be resolved.

phenomena which it is the purpose of natural science to demonstrate and explain. We have only to advert to water, to show that this fluid may be reduced to the most varied and dissimilar conditions by the influence of heat, or by chemical decomposition. By lowering the temperature, we freeze it into ice; by raising it, we thaw it; by an increase of heat, we convert it into vapour; while we can again condense this vapour into water. By galvanic agency, we reduce it to its elements, the oxygen and hydrogen gases of which it is composed. Metallic substances are capable of like transmutations from the most solid form to that of vapour. These facts, combined with others,—the internal heat of our globe, its volcanic eruptions, its vaporous exhalations and thermal springs,—serve to demonstrate the extreme probability of our planet having condensed to its present solidity, from a fluid or gaseous state; which this hypothesis assumes as its original condition.

Internal Heat of the Earth.—That the earth possesses a source of internal heat, is a fact which is demonstrated by the phenomena already mentioned. The increased temperature of wells and mines, the warmth of which augments in a known ratio as we descend; the vaporous exhalations of the earth, its streams of heated water, and its volcanic eruptions, all prove the existence of such a cause. To an agent thus powerful and universal many of the modifications of the earth's surface are evidently attributable, as the fusing of the melted rocks, and the altering of those which are termed metamorphic, while its operation in existing volcanoes is alike evident. The only doubt of importance is as to the nature of these subterranean fires: one section of observers, among whom Humboldt, Fourier, Cordier, and Arago, maintain the views of Leibnitz, as to their resulting from the original incandescence of our planet; the other, attribute them to chemical agencies operating within the depths of the earth. Meantime there are various facts, such as the mean density of our earth, which is too small to allow of its being wholly a solid mass; together with the undulatory motion observed in earthquakes, with other phenomena of similar nature, which lead to the conclusion, that a large part of the interior of our planet is in a state of fusion by heat, and that we are existing on the

external covering of a mass of molten matter. The oscillations of such a fluid tending towards different directions, will sufficiently account for physical phenomena of the highest relative interest and importance, such as the changes in the external aspect of the earth by the elevation of continents from the bed of the ocean, the upheaval of some portions of the surface, the submergence of others, and the general variety observable in its configuration.

Crust of the Earth.—We are naturally directed to this crust, or *Erdrinde*, (as the Germans term it,) as the legitimate sphere of geological investigation. These terms are used in a general sense, and without reference to any theory as to its internal structure or contents. It will be best understood if we describe it as that portion of our planet which is accessible to human observation. It is composed of a number of substances more fully to be described hereafter, which under the name of rocks comprise every element and combination, from loosely coherent beds of sand and gravel, to crystalline strata and masses of granite; and from the ashes and scoriæ of volcanic ejections, to the hardest and most compact kinds of trap and basalt.

The crust of the earth, although an infinitesimal quantity when compared with the mass of the globe itself, is of immense extent and importance. As regards its thickness, which is estimated at about ten miles, it bears, in a physical point of view, no greater relation to the mass of the globe than that which would be offered by a film of gold leaf coating the rind of an orange; regarded under another aspect, it is the theatre of land and water, of mountain and valley, of ocean, river, and lake, and affords a sphere for the existence of the animal, vegetable, and mineral kingdoms.

Order and Succession of the Rocks.—The constant order of sequence of the several geological formations constitutes one of the most important lessons which this science teaches; on this fact the first principles of geology are based. At a period comparatively recent, the utmost ignorance prevailed as to the structure of the earth. It was regarded as a confused mass of inorganic matter, where heterogeneous substances were mingled indiscriminately together. It was known that at some places solid rocks rose to the surface, and that in other regions they were absent; but their order,

succession, and continuity were unsuspected; for the laws which determine these results were unknown. It was reserved for geology to deduce harmony and regularity from apparent discord and confusion,—to extend the domain of philosophy, and to enhance our conception of the Supreme Being by revealing to us past spheres of his creative wisdom and power. The arrangement of the various formations may be represented by an alphabetical series from *a* to *z;* and this order, though it is frequently imperfect, is never inverted. We often miss one or more terms in the series, and lose, say the *b*, or *h*, or *m*, or even several letters in succession; but we never find the *b* taking the place of the *a*, or the *d* preceding the *c*, or any member of the series usurping the position of another which ought to go before it; in other terms, we never meet with the entire series of deposits in one place, but those which do occur invariably follow the regular order of sequence.

TROPICAL CLIMATE OF THE ANCIENT EARTH.—Among the varied contrasts afforded by the past and present condition of our globe, must be enumerated the fact so clearly demonstrated by the organic remains entombed in the fossiliferous rocks, that the climate and character of the productions now limited to the immediate vicinity of the equator, once extended to latitudes far removed from that line. It is only, says M. Deshayes, in the second era of the tertiary period,* the miocene, that the climate of the earth cooled, from a degree of heat exceeding that of the equator, to a temperature equivalent to that of Gambia and Senegal, while it was only at the third and more recent epoch that it assumed a European character. These results were deduced from the comparison of a suite of fossil shells from the tertiary strata of France, with a series of recent species from the localities above mentioned. The observations of Count Sternberg, on the flora of the ancient periods, indicate analogous changes in the vegetation of these eras; while the discoveries of Cuvier, Agassiz, Owen, and Mantell afford similar testimony as to the vertebrate fauna of the secondary rocks. If we examine the fossiliferous strata with this view, commencing with the most ancient, we shall find that the

* Coquilles Fossiles des Environs de Paris, p. 779.

organic remains they contain consist of forms of zoophytes allied to such as are indigenous to tropical seas; the shells, to genera and species that live in the seas of the torrid zone. The crustacea are analogous to those of India, and the fishes indicate a tropical clime. The carboniferous period affords evidence derived from the land, which confirms that obtained from the ocean. The flora of this period is remarkable for the great proportion of monocotyledonous over the dicotyledonous plants—of trees allied to the fern, the palm, the cane, and the bamboo; the luxuriant growth of vegetable life—the great development of types of structure, as ferns and club-mosses, into organisms of the magnitude of forest trees—the enormous extent of this vegetation, reaching, as it does, from Europe to Australia, with other characters, derived from comparison with allied genera of existing tropical plants, prove that the earth, during this period of its history, possessed a universal climate, the heat of which was not merely as great as that of tropical regions in our day, but which Adolphe Brogniart conjectures as far surpassed that of our tropics, as these exceed that of the temperate zone of our time. As we advance onward, we meet with accumulating proofs of the same fact. On arriving at the new red sandstone, we reach the dawn of that age of reptiles which extended to the close of the secondary rocks, the discovery of which is due to the comparative anatomists of the nineteenth century.

Various hypotheses have been proposed to account for this change of climate. Sir C. Lyell has suggested that a reversal of the present distribution of the land and sea would afford a sufficient cause; and has imagined that, if a greater development of land now prevailed in the southern hemisphere, and of water in the northern, as is presumed to have been the case in the early conditions of our globe, its ancient climate would be restored. Mr. Babbage, with considerable appearance of probability, has sought the cause in the radiation of internal heat, suggesting that the accumulation of fresh deposits, and the substitution of sedimentary substances, which are bad conductors, for water, which is a good conductor of heat, may have been adequate to the result. Other inquirers have referred the change to astronomical causes, and Sir John Herschel has recently suggested an

ingenious hypothesis. He first states that the amount of heat derived by the earth from the sun increases or diminishes with the eccentricity of the earth's orbit; and that this eccentricity is known to be slowly decreasing. He next shows that the actual eccentricity of many of the planets is known to be very considerable indeed; and concludes that we have only to form the very natural conception, that this eccentricity of the earth's orbit was formerly greater than it now is—equal to that of several of the planets, to arrive at the conclusion that the slow diminution of such eccentricity may have produced a refrigeration of climate equal to that indicated by the geological phenomena just described.

Whatever may be the cause, the fact is indisputable; the tropical climate of the primeval earth is demonstrated by the character of its productions; and we are compelled to admit that a cause then prevailed, or, possibly, a combination of the causes above enumerated, which was sufficient to overcome the effect of the diurnal and annual motion of the globe, and to render its surface a vast hothouse, calculated for the growth of ultra-tropic forms of animal and vegetable life; while the circumstance is one which the student must regard, not merely as an abstract truth, but as a principle fraught with the most useful and instructive application. No lesson in science is more difficult than that which teaches us to dismiss impressions which early associations have rendered familiar, and to substitute opinions which, though more correct, are strange and new. In investigating the ancient history of the earth, we must change land to sea, and sea to land; we must transport ourselves to distant regions, and to torrid climes; we must regard its oceans as vyeing in extent and grandeur with the Atlantic or Pacific, abounding in coral reefs and islands, and with tropic forms of marine life; its lakes as inland seas; its rivers such as to rival the Amazon or Mississippi; its forests groves of ferns, canes, palms, bananas, and bamboos; its plains luxuriant savannahs, overgrown with grasses and gigantic reeds, which sheltered and supported gigantic reptiles; the whole scene must present the panorama of a torrid clime, with its colossal forms of animal and vegetable existence.

Arctic Climate.—From various phenomena which have

already been mentioned, in particular the occurrence of erratic blocks, the presumed existence of icebergs, glaciers, and fields of ice, as well as from the arctic character of many fossil shells, it is conceived that at a comparatively recent period, probably towards the close of the tertiary epoch, the tropical temperature of the ancient earth was succeeded by a climate of greater cold than now prevails in the same regions at the present day.

EXTINCTION OF VARIOUS GENERA OF ANIMALS.—This fact will be more fully exposed in our chapter on Palæontology. It may be stated in general, that when the physical conditions of climate, &c., were favourable to certain forms of animal life, they existed; when the conditions changed, they became extinct, and their places were then filled by others better adapted to the new conditions of the globe;—one species or genus became extinct after another, its place being occupied by a new form; so that after a certain period, the fauna of a country was gradually but completely changed.

In proportion as we recede in our investigation from the present into the past, do we meet with species and genera that no longer exist; and in like manner as we trace animal forms from the ancient organisms of the Silurian strata up to those of the tertiary period, do we encounter types that blend with those of the human epoch.

OPERATION OF MODERN CAUSES.—The consideration of this subject involves the statement of so many facts, and the study of such varied phenomena, that we must refer the student to the admirable philosophical principles of Sir C. Lyell,* for an able exposition of the causes now in operation by which the earth's surface is slowly changed. The following *resumé* may be useful, by directing his attention to a careful study of this most interesting and instructive branch of physical investigation:—

1. The natural world is the theatre of incessant movements, which are governed by laws that are fixed and immutable.

2. The changes that have occurred in the earth's surface in past time are essentially the same as those now at present in progress.

* Principles of Geology, vol. i. 2nd edit.

3. The vast cycles of time through which these physical agents have operated, accomplish by their duration what they lose in force.

4. For these reasons, the history of the past is believed to explain and illustrate the present, and should be diligently studied, for the right understanding of geological phenomena.

5. Although nature's course is generally one of repose and incessant orderly action, still the volcano, the earthquake, and the flood occasionally disturb the harmonious play of its hidden and silent operations; just as the serenity of the atmosphere is occasionally overcast by the storm, or visited by electric phenomena. In both cases the disturbing causes are destined to effect an ultimate good, and work out the predetermined designs of their Omnipotent Author.

EXERCISES.

The statements of the foregoing chapter constitute so many exercises. The following examples may be added for further illustration :—

1. The first lesson, that such studies enable us to appreciate the attributes and perfections of the Deity, is enforced by every inquiry into his works. The mineral, the vegetable, and the animal kingdoms vie with each other in displaying the perfections of their Author; and as geology is only another name for the combination of all the studies of nature, it is evident that no other pursuit can afford such numerous and instructive proofs of the benevolence and wisdom of the Creator.

2. In illustrating the antiquity of the earth from the foregoing chapter, the object will be facilitated by the student converting its statements into questions, and rendering the answers which are calculated to explain them. He will further find it expedient to insert these in his note-book, and to enter under each respective head the information which bears upon the particular fact.

3. The modern date of man, as contrasted with that of the earth he inhabits, is a truth so self-evident as to require no effort for its demonstration; on this and other statements of the present chapter the difficulty would be, not to establish the facts, but to discover a single argument that would militate against them.

4. On the internal heat of the earth, the student will find ample information in the works of those authors mentioned in the text: questions of so abstruse a nature are fitter for the proficient than the student: he may rest satisfied at the outset with the fact of the internal heat of the earth, without indulging in speculations as to its origin.

5. The nature of the crust of the earth, and the texture, order, and succession of the substances of which it is composed, are themes respecting which it is scarcely possible to

suggest any definite exercises, further than the mode already pointed out, of self-examination by converting the statements of the previous chapter into questions, and returning the appropriate answers.

6. The tropical climate of the ancient earth, the changes in the types of animal and vegetable life consequent on its refrigeration, and the nature and effects of modern causes, are, in like manner, facts respecting which no exact tasks can be assigned; the student will find the most instructive mode of studying these and similar principles, to consist in transferring the heads of them to his note-book, and making them the subject of those remarks and illustrations which will not fail to suggest themselves in the course of his geological studies.

CHAPTER IV.

Qualifications of a Geologist—Instructions for the Beginner—Practical Hints for commencing the Study of the Science—Scientific Institutions—Works on Geology—Collecting and arranging Fossils—The Microscope.

Qualifications of a Geologist.—It will be perceived, from the foregoing remarks, that geology is a science far too extensive to be successfully studied, in all its details, by any single mind. In fact, the perfect geologist, like the perfect orator of the Roman writer, is to be regarded rather as a creature of the imagination than of real life. Such a person ought to be versed in the complete circle of science, philosophy, and letters, and possess attainments which a whole life is insufficient to acquire. He should be acquainted with mathematics and physics, that he may be enabled to judge of the nature and importance of the facts submitted to his investigation. He should base his researches on a study of mineralogy, that he may be enabled to judge of the internal structure and external characters of minerals and their combination in rocks. He should possess a knowledge of the theory and practice of chemistry. He should acquire an extensive and well-founded acquaintance with conchology, that he may attain the power of detecting the minute but characteristic distinctions of species and varieties of recent and fossil shells. His skill as a botanist should be accurate and profound, so as not only to enable him to describe a recent plant, but to determine from the fragmentary mineral relics of vegetation, from the veins of a leaf, the markings of a stem, or the character of a seed-vessel, the tribe or family to which the plant belongs.

He should not only be so far acquainted with comparative anatomy, as to be able to identify the character of a tooth or a bone; but he should possess a profound knowledge of the laws of structure, to enable him to reconstruct

a skeleton out of its fragmentary parts, and restore to their natural places in the series, the animal forms that inhabited the ancient earth. He should possess the accomplishments of a draughtsman, and, to some extent, the skill of a surveyor. He should be proficient in the learned languages, to enable him to deal with the delicate question of nomenclature; and should, in like manner, be versed in modern tongues, for the purpose of corresponding and conversing with foreign philosophers, and reading their works. It is obvious that pursuits thus varied and extensive can scarcely be combined in any one individual:—

> "Natura certè
> Multa tegit sacra involucra, nec ullis
> Fas est scire, quidem, mortalibus ómnia!

Since, therefore, none of our living geologists can boast the whole of these attainments, though many possess a considerable part thereof; and since the mastery over subjects so profound and extensive is obviously not to be acquired by a single person, geology becomes, in an eminent degree, a co-operative pursuit. Accordingly, our best geologists, while they devote due attention to the general objects of the science, confine their energies to some single department, and bring to the general stock the information they individually acquire. In a science thus dependent on many, the efforts of all are useful; and while no labourer can call the territory his own, even the tyro may contribute to its progress. A very moderate acquaintance with its leading principles and auxiliary studies will authorise us to commence our career; an equally moderate share of application will enable us to pursue it with satisfaction. When we have acquired the general outlines of the science—when we are acquainted with the nature and classification of the various formations—when we can distinguish aqueous from igneous deposits, and stratified from unstratified rocks—when we can specify the sedimentary deposits, and recognise them by their distinguishing features of mineral character, superposition, and characteristic fossils—when we know some ten or twelve of the simple minerals, and can detect their combination in rocks—when we are acquainted with the genera of shells appertaining to each formation, and have filled a few drawers with fossils, and can bestow on each its local

habitation and its name, we may commence a career, the further success of which will depend solely on our energy and application.

The first difficulties, however, are ever the most arduous; and, with the view of assisting the student to surmount them, we shall furnish a few practical hints, which may tend to facilitate his progress, and render his task comparatively easy and delightful.

THE SCIENTIFIC SOCIETIES AND OTHER ADVANTAGES AFFORDED BY THE METROPOLIS.—The student, if a resident in the capital, should, in the first place, procure a ticket of admission to the library of the British Museum, by which he will obtain access to works too voluminous and expensive for a private collection. Such a ticket is to be procured by applying to the principal librarian, and producing a recommendation satisfactory to a trustee or an officer of the house.

He will also find it expedient to avail himself of the advantages afforded by the scientific collections of the Museum; and the departments of Zoology, Botany, Mineralogy, and Fossil Organic Remains, may be advantageously studied with the aid of the Synopsis.

The Geological Society will conduce, in an important degree, to his information; he should inspect its collections, consult its Transactions, and, above all, attend its meetings.

The Museum of Economic Geology, Jermyn-street, is an establishment, the importance of which is only beginning to be appreciated by the public. It has long been a matter of regret, that we possess no School of Mines, analogous to those establishments on the Continent, where instruction in the elementary departments of mining, and its associate sciences, could be procured. Sir H. T. Delabeche has, however, prevailed on the Government to supply the deficiency, by forming a museum for the collection of fossils,* ores, minerals, building-stones, models of mines and works, together with an office for the records of mines.

The Royal Institution will afford excellent opportunities for acquiring chemical and general scientific knowledge. The Linnæan, Zoological, Entomological, and Microscopic

* Ably superintended by Professor Forbes.

Societies offer facilities for the prosecution of those studies which they are especially designed to promote. The means of obtaining scientific information have also been largely increased by the establishment of King's College and the London University, where lectures on the leading branches of science are delivered by the professors.

Works on Geology.—The works best adapted for each particular department will be named under their respective heads. We shall now enumerate, in alphabetical order, those publications calculated for the general study of the science.

The Introduction to Geology, by Mr. Bakewell, is an instructive and useful work; especially as regards the mineralogical department of the subject.

The Bridgewater Treatise, by Dr. Buckland, contains an exposition of the chief phenomena of geology, and of the design of the Deity, as displayed in the creation. In pictorial beauty, accuracy, and taste, this work is, perhaps, unrivalled in scientific literature.

The works of Sir H. T. Delabeche are numerous and important; his Manual contains an instructive account of the various formations; while his other writings are eminently valuable for the information they afford on physical geology.

The writings of Sir C. Lyell are of a high order of merit. His admirable Principles contains a valuable collection of facts, with the most able and philosophical reasoning on them; his Elements, though professedly designed for students, are replete with instruction for those who are proficients in the study.

The writings of Dr. Mantell are deservedly prized, both by the scientific and general public. The Fossils of Tilgate Forest contain an account of his remarkable discoveries in that district, which he has rendered classic ground for the geologist.

The Silurian System of Sir R. Murchison comprises, not only a most accurate delineation of the region explored by this indefatigable observer, but an instructive review of the phenomena connected with the middle and lower formations. It is, in fact, the most splendid monograph which has yet appeared in the scientific literature of this or perhaps any other country.

Professor Phillips's treatises on geology, in the Encyclopædia Metropolitana and the Cabinet Cyclopædia, are valuable; and his Guide is an admirable epitome of facts.

The Geology of England and Wales, by Conybeare and Phillips, is the student's best guide for the geology of our island, and will long remain a monument to the industry of its authors, and a useful compendium of carefully compiled facts.

The Catalogue of British Fossils, by John Morris, Esq., is an indispensable hand-book; and Mr. Tennant's smaller work on the same subject should be in the library of the student.

It is impossible to pass over, in the list of writings on geology, the able and learned treatise of the Rev. Dr. Pye Smith, in which he attempts to reconcile the discoveries of geology with the facts related in Scripture, and to demonstrate the perfect harmony of science with Revelation.

The above are the most important and valuable publications in our language; and the student may safely commence his studies under the guidance of these works.

A Dictionary of Geological Terms will be found extremely useful; and that of Dr. Humble, or the smaller publication by Mr. Roberts, may be consulted with advantage.

The Geological Chart of Sir H. T. Delabeche will prove highly instructive: a good geological map will also be indispensable; that of Mr. Greenough, which is published under the sanction of the Geological Society, is the largest and most comprehensive. The large Geological Map by Mr. Knipe, or the smaller one published by the Society for the Diffusion of Useful Knowledge, are both very valuable.

Mr. Bartlett's *Index Geologicus* presents, at one view, a sketch of the whole succession of the deposits—their animal, vegetable, and mineral characteristics, together with an account of their agricultural soil and productions, and is useful for reference.

We cannot too strongly impress on the student the great advantage of a common-place book. He should, indeed, have one for each department—general geology, the minerals, the animals, and the plants. It should possess an index, and if he enter under its proper head the works of the various authors on these subjects, the fresh discoveries

continually made, and all the information he can collect, he will very speedily find this to be the best and most instructive volume in his library.

Collecting Fossils.—If the student reside in a district abounding in fossils, as, for example, the crag, chalk, oolite, lias, coal, or Silurian formations, the task of forming a collection will be rendered comparatively easy, since his immediate neighbourhood will afford an abundant supply of specimens; by exchanging the productions of his own locality for those of another, he will be able, with the aid of a few occasional purchases, to form a collection calculated, not only to minister to his own improvement, but to contribute to the advancement of science. The largest and most important collections have been accumulated under circumstances unfavourable to the prosecution of such pursuits, and under difficulties and discouragements calculated to repress them. Amid other and more pressing occupations, as a solace in the evening from the occupations and fatigues of the day, have these treasures been gradually collected, until the cabinet of the amateur has grown into the public museum; and, as in the case of Dr. Mantell, has been deemed worthy of acquisition by a nation.

Arrangement of a Cabinet.—The simplest mode of arranging a collection is, by placing the specimens in drawers sufficiently deep to receive them. The shells should be gummed on boards covered with paper. Wherever it is possible, two specimens of a species should be obtained, to display both back and front thereof; and when the fossils are peculiarly interesting, the number may be increased.

Drawers fitted up with small boxes made of card-board of different sizes, and closely packed together, will be found very convenient for arranging specimens, especially such as bear handling without injury: this plan has many advantages, and permits a much larger number of shells to be packed away in a cabinet than any other we are acquainted with.

The arrangement should be in descending order, commencing with the most recent formations, and proceeding to those of more ancient date.*

* The reader is referred to the Instructions at the end of this volume for collecting Specimens of Geology, published by authority of the British Museum; which is from the pen of C. König, Esq., keeper of the minerals in the National Establishment.

The Microscope.—The perfection to which the optical and mechanical construction of the microscope has attained, has conferred upon the naturalist an inestimable boon. Every department of nature abounds with objects that cannot be fully studied by the unaided eye alone, and thus magnifying powers are necessary to unfold the intimate structure of a large class of organic bodies; a good microscope therefore becomes indispensable to the geologist. This proposition is proved by a brief statement of what its aid has effected in palæontology. Professor Owen observes—"By the microscope the supposed monarch of Saurian tribes, the so-called *Basilosaurus* has been deposed and removed from the head of the reptilian to the bottom of the mammalian class. The *Saurocephalus* has been degraded from the class of reptiles to that of fishes; it has settled doubts entertained by some of the highest authorities in palæontology, as to the true affinities of the gigantic *megatherium*, and by demonstrating the identity of its dental structure with that of the Sloth, has yielded us an unerring indication of the true nature of its food."

Important results have been obtained by the investigations made by Messrs. Quekett and Bowerbank, on the intimate structure of bone; from which it appears that the form, size, and structure of the bone-cell alone is sufficient to decide the class to which a doubtful specimen belongs. The researches of these gentlemen will be referred to more in detail in our chapter on palæontology.

Dr. Carpenter has shown that the microscopic structure of shell affords important data for settling doubts upon the affinities of certain families of the Mollusca; and Dujardin and D'Orbigny have more fully described by its aid the singular and interesting group of shells known as Foramenifera, which are so abundant in rocks of the cretaceous and tertiary periods. Ehrenberg has shown that many deposits in the tertiary series of Bohemia are composed of the silicious shields of fossil infusoria; and the same fact has been observed by the microscopists of our own country.

This instrument is equally valuable to the investigator of the remains of the earth's ancient Flora; sections of the vegetable structure assist the observer in deciding the families to which the floras of successive periods belonged;

and he is indebted to its aid for much valuable information on the plants which flourished during the carboniferous era. The student should therefore procure a microscope, and commence a series of independent observations. The best microscopes are those made by Messrs. Powell and Lealand, Mr. Ross, and Messrs. Smith and Beck, in London; the object-glasses made by these gentlemen are of a first-rate class, and their penetrating and defining powers have never before been equalled; object-glasses made by the English opticians are most desirable.

Mr. Thomas King, of Bristol, makes beautiful instruments; his small portable microscope, and his educational one, are well suited for geological and all other purposes. A series of objects illustrative of palæontology, may be obtained from Mr. Topping,* Mr. Darker,† and others: when the student has made himself acquainted with the character of bone, teeth, shell, and wood, he may proceed to make thin sections of these objects, which must be mounted in Canada Balsam; he will soon make a valuable collection by this inexpensive process.

* New Winchester-street, Pentonville Hill.
† Paradise-row, Lambeth.

CHAPTER V.

MINERALOGY.

Outline of the History of the Science—Crystallisation—Crystalline Forms—System of Mohs—Instructions for Forming a Collection—Investigation of the External Characters of Minerals—Use of the Blowpipe—Practical Exercises, &c., &c.

AUTHORS:—Phillips, Brooke, Griffin, the Abbé Haüy, Beudant, Werner, Berzelius, Weiss, Mohs, Neumann, &c., &c.

COLLECTIONS:—The British Museum, and the Collections of the Universities and Public Institutions.

THE science of geology consists essentially of mineralogy, physical geology, fossil botany, and palæontology. As these pursuits are of the most extensive nature, and each would, in fact, demand the study of a life fully to acquire it, we shall content ourselves with offering that elementary and practical information which will serve as an introduction to the larger works, to which we refer the student for more ample particulars.

We have already remarked, that a proper acquaintance with mineralogy must form the basis of geology. There are substances of common occurrence, so similar to each other, that they can only be discriminated by an acquaintance with mineralogy and by the operation of the blowpipe. Some varieties of feldspar so closely resemble certain kinds of hornstone, that they can only be recognised by being fusible, while many of the plutonic and volcanic rocks are so nearly alike, that a knowledge of mineralogy can alone enable us to distinguish them. We may further add, that the Germans, who study every science so profoundly, exact from the student at their universities, a due proficiency in mineralogy, before he is allowed to commence the pursuit of geological science.

The following outline of the progress of mineralogy is

compiled from various sources, and among others from Professor Whewell's History of the Inductive Sciences, to which the student is referred for more extensive details.

The information possessed by the ancients on the subject of minerals appears to have been most scanty: and the progress made towards a just appreciation of their nature and qualities, in modern times, has been extremely gradual.

Several of those writers who have been mentioned in our sketch of the history of geology, are alike honourably associated with that of mineralogy. Thus the celebrated Gessner is the first who has written on crystallography. Palissy delivered and published lectures on mineralogy at Paris. The work of Encelius (1557), though mingled with the follies of alchemy as regards the composition of minerals, is quoted with approbation, as presenting judicious views of general classification. Cesalpinus and Schwenkfeld, of Silesia, are eulogised as having published attempts at mineralogical classification, which are regarded as extremely satisfactory for a period when chemistry was so little advanced. Cesius, Georgius of Stockholm, and Aldrovandus wrote on the arrangement of minerals, dividing them into earths, solidified fluids, stones, and metals. Their ideas, though mingled with the errors of alchemy and the cabala, are often reasonable.

Stenson, the Dane, is noticed as having been the first to observe the constancy of form in crystals; since he remarks in the work already mentioned, which was published in 1669, that though the sides of an hexagonal crystal may vary, the angles do not.

Dominic Gulielmini, in a dissertation on salts, published in 1707, adopts the same views, observing that, "since there is here a principle of crystallisation, the inclination of the planes and angles is always constant;" and Professor Whewell assures us that he anticipates very nearly the views of later crystallographers, as to the mode in which crystals are formed from elementary molecules.

These writers were followed by others, who, without achieving any great discoveries themselves, led the way by their labours to the results subsequently obtained by others, and acted as pioneers in the advance which the science was destined to make. Among these are enumerated Cap-

peller, who published his *Prodromus Crystallographiæ*, in 1723; Bourquet, whose *Lettres Philosophiques sur la Formation de Sels et de Cristaux* appeared in 1729; and Henkel, the *physicus*, or naturalist, of the Elector of Saxony, whose *Pyritologia* is dated 1725.

This last writer, though his researches are fettered by his literal interpretation of the Mosaic writings, was extensively acquainted with mineral productions, and has given some valuable information on metallic veins.

Bromel, a French mineralogist, has the honour of being the first (1750) who classified mineral substances according to their pyrognostic qualities, (those induced by the agency of heat,) in combination with their external characters. Cronstedt shortly after applied a mode of classification previously unknown, to which all the characters of mineral substances were submitted, since he was the first who took into consideration their elementary composition.

It was reserved, however, for Linnæus to arrange minerals according to their mathematical forms; but though the intuitive sagacity of that great man, observes Professor Whewell, led him to perceive that crystalline form was one of the most definite, and therefore the most important of the characters of minerals, he is conceived to have failed in profiting by this idea; because in applying it he did not employ the aid of geometry, but was guided chiefly by what appeared to him resemblances, which, however, were arbitrarily selected and often delusive. His efforts led to those of a highly successful labourer in the same field, Romé de l'Isle. The great obstacle which lay in the way of these inquiries, consisted in the difficulties presented by the secondary forms of crystals: since, in consequence of the apparent irregularities of these forms, arising from the extension or contraction of particular sides of the figure, each kind of substance may appear under very different forms; which, however, though apparently dissimilar, are connected with each other by certain geometrical relations. These may be imagined by conceiving a certain fundamental form, to be cut into new forms, in particular ways. Thus, if we take a cube and cut off all the eight corners till the original faces disappear, we shall make it an octohedron. This truncation of angles and edges had already been noticed by Demeste; while the

celebrated Werner had published a *Systema Mineralogicum*, in which he had formally spoken of replacement by a plane, an edge, and a point, as methods in which the forms of crystals are modified and often replaced. The wider application of the plan was, however, due to Romé de l'Isle, who in his turn was eclipsed by the celebrated Haüy; who by the variety, extent, and importance of his researches, during a long life, exclusively devoted to mineralogical inquiries, may be regarded as the founder of the school of modern crystallography; those who followed him having taken his views either wholly or in part as their basis. He was the first who successfully investigated the mathematical structure of crystals, taking up the subject where it had been left by Romé de l'Isle. He determined the primary form of every mineral, and showed how the secondary forms were derived from it by simple laws of decrement. The knowledge of these primary forms enabled him to arrange minerals with more precision than had been done before him. He defined a mineral species to be a substance compounded of the same constituents, united in the same proportions, and possessed of the same crystalline form. The chief defects of the system of Haüy, as contrasted with the present state of the science, consist in the method adopted by him of imposing a separate name on every secondary crystal, and considering it as existing by itself. This multiplicity of names renders it excessively difficult, it might be said impossible, to remember all his secondary forms when they are very numerous, as happens with respect to calcareous spar, sulphate of barytes, iron pyrites, &c.; and the perusal of his book is thus rendered so irksome, that it can hardly be undertaken without some specific object. But the grand defect of his system consists in the inaccuracy of his measurements, which were made only by the common goniometer, an instrument not susceptible of giving the angle within half a degree of the truth. After the invention of the reflective goniometer by Dr. Wollaston, which is capable of measuring angles within one minute, the angles of all crystalline bodies were again examined by other mineralogists; and it was found that those assumed by Haüy were very seldom the true ones, differing from the real measurement frequently by several degrees. This general inaccuracy has rendered the measure-

ments and calculations of Haüy of comparatively little value.

It may here be expedient to offer a brief definition of the recent discoveries of those laws of chemistry, which have so intimate a relation with the nature and composition of minerals.

Isomerism, discovered by Berzelius, is a principle which is somewhat vague and doubtful in its application; it may be defined as that law by virtue of which bodies having the same molecular composition, and the same atomic weight, have different physical properties.

Isomorphism is the law by which an equal number of atoms, combining in the same manner, may give birth to similar crystalline forms, although the constituent elements are of a different nature.

Dimorphism is a law which, though previously known, has been confirmed by the discoveries of Mitscherlich. It is considered to be only a peculiar kind of isomerism.

The law of equivalents is that by which bodies combine with each other in constant and invariable quantities.

The law of substitutions shows that constituent elements may be substituted for each other, without producing any change in the nature of the compounds. This law, which is perhaps a peculiar case of the law of equivalents, was fatal to the electro-chemical theory of Berzelius, since it proves that electro-positive bodies may be substituted for electro-negative, and vice versâ.

The most important additions, since the period of Haüy, have been made by the endeavours of Weiss and Mohs to establish distinct systems of crystallisation, founded on essential distinctions of crystalline form. Professor Weiss showed the importance of considering the axes in crystals, and established on these the distinction and classification of crystalline systems; he also published a theory of zones, calculated to facilitate the development of compound forms, which has served as the basis of the representatives of crystalline forms to two of his pupils, Neumann and Quenstedt. Professor Mohs gave a new exposition of the principles of crystallography, and published a remarkable classification of minerals, founded solely on their physical characters. He was followed by Breithaupt, Haidinger, and Zippe. Neumann proposed a new notation of crystal-

line forms, much more simple than those of Weiss and Mohs, and published in 1830 a treatise on crystallography, which is regarded as the most learned and complete work we possess on the subject.

The principles assumed by the Germans have received considerable confirmation from the brilliant optical discoveries of Sir David Brewster. The system of Mohs, in particular, is generally adopted, and with the discoveries which confirm it, will be explained, in a future page; his nomenclature of single minerals, however, from being cumbersome and difficult, has failed. The two electro-chemical systems introduced by Berzelius are conceived to be imperfect. His first attempt was to class all minerals according to their electro-positive element, and the elements according to their electro-positive rank; but the discovery of isomorphism, and the law of equivalents, virtually annihilated the system. These celebrated discoveries were, in substance, as above-stated, that certain substances assuming the same crystalline form may be substituted for each other in combination, without affecting the external character of the compound. Hence, since bodies with very different electro-positive elements could not be distinguished from each other, it became impossible to place them in distant parts of the same classification. The second attempt, by the same philosopher, to found a classification on electro-negative qualities, is declared by our able English historian of the sciences, to be no more trustworthy; for he observes, if the electro-positive elements are isomorphous, the electro-negative elements are sometimes isomorphous also, and cites the arseniates and phosphates in proof of his assertion.

As the summary of this brief sketch of the history of the science, it may be stated that the systems hitherto proposed can scarcely be regarded as satisfactory or complete, though we should recommend the reader to study that of Mohs as the theory most generally received. The present state of our knowledge in this, as in other departments of science, is confessedly imperfect; the labours of the distinguished men whom we have enumerated, are to be regarded as approximations to the truth, rather than as the truth itself; and to borrow the conclusion of that author to whom we are so largely indebted for the information here detailed, "The

combination of chemical, crystallographical, physical, and optical properties into some lofty generalisation, is probably a triumph reserved for some future and distant period."

Meantime, it is satisfactory to know, that if the theory of mineralogy continues uncertain, its practical departments have received considerable extension and improvement. Other philosophers have also promoted, by their discoveries in kindred studies, the progress of this pursuit. The chemical researches of Sir Humphry Davy have proved the metallic bases of the earths and alkalis; while other inquirers have shown that acidity is not an absolute but a relative quality, and that there are substances which, united to certain bodies, act as acids, and with others become bases. While the invention of the reflective goniometer, by Dr. Wollaston, with the addition of the mirror by Mr. Sang, has brought the measurement of crystals to mathematical precision; the application of the blowpipe to the purposes of mineralogy, by Andreas Swab, has formed an era in the study; this instrument, in the hands of Bergman, Gahn, and Berzelius, has essentially contributed to perfect our inquiries into the physical and chemical relations of the science.

It may be expedient, before we enter further on the subject, to give an outline of the general qualities of elementary substances.

The chemist divides bodies into simple and compound; the simple being, those out of which nothing different from themselves can be obtained; the compound, those which consist of two or more elements. It may be cited, as a fact indicative of the progressive character of chemical inquiry, that the number of simple substances, known in 1787, was seventeen; in 1802, it was twenty-eight; whereas we are now acquainted with fifty-five. If it be objected, that many substances now considered simple may probably be compound bodies, which more perfect instruments, or more powerful re-agents, will enable us to discover; it may be fairly assumed that there are elementary substances yet undiscovered, which further researches may bring to light.

The elementary bodies at present known may be conveniently classed under the following heads:—

Five gases, or vapours — oxygen, hydrogen, nitrogen, chlorine, and fluorine.

Seven non-metallic solids and fluids—sulphur, phosphorus, selenium, iodine, bromine, boron, and carbon.

Three metallic bases of the alkalis—potassium, sodium, and lithium.

Four metallic bases of the alkaline earths—barium, strontium, calcium, and magnesium.

Six metallic bases of the earths — aluminum, silicum, yttrium, glucinum, thorinum, and zirconium.

Thirty metals, whose combinations with oxygen produce neither alkalis nor earths—

1 Manganese	11 Uranium	21 Mercury
2 Iron	12 Columbium	22 Silver
3 Zinc	13 Nickel	23 Gold
4 Tin	14 Cobalt	24 Platinum
5 Cadmium	15 Ceranium	25 Palladium
6 Arsenic	16 Titanium	26 Rhodium
7 Molybdenum	17 Bismuth	27 Osmium
8 Chromium	18 Copper	28 Iridium
9 Tungstenum	19 Tellurium	29 Vanadium
10 Antimony	20 Lead	30 Lantane.

Of these metals, the first five decompose water at a red heat. The next fifteen do not decompose water at any temperature, and their oxides are not reducible to the metallic state by the action of heat alone. The oxides of the rest are decomposed by a red heat. It may be added, that of the above there are not more than sixteen elementary substances which are of any importance in the formation of the earth itself or the atmosphere which surrounds it, and consequently which possess any especial claim on the attention of the geologist. These substances are—

Oxygen	Sulphur	Silicum	Magnesium
Hydrogen	Chlorine	Aluminum	Calcium
Nitrogen	Fluorine	Potassium	Iron
Carbon	Phosphorus	Sodium	Manganese.

Of the above elements, oxygen is the most important. It forms more than one-half of the globe, constituting eight tons in every thirty-six of air, eight in every nine of water, nearly a half of the more abundant earths, — silica and alumina besides being present in almost all vegetable and animal substances.

Were these bodies perfectly free to combine with each

other, the amount of such combinations would be infinite, and the number of minerals endless; but their combinations are limited by two important laws; the first of which is, that certain substances have so strong an affinity for each other as to combine and prevent combination between others whose affinities are more feeble; while in all bodies which are chemical combinations, and not mere mechanical mixtures, the ingredients unite only in definite and invariable proportions. Thus hydrogen unites only with eight times its weight of oxygen to form water; while this is the lowest proportion in which oxygen enters into combination. The following explanation of chemical nomenclature, extracted from the excellent work of Dr. Turner, will convey, not only an explanation of mere terms, but with these, of the most important principles of chemistry as connected with mineralogy.

"Chemistry," he observes, "is indebted for its nomenclature to the labours of four celebrated chemists—Lavoisier, Berthollet, Guyton Morveau, and Fourcroy. The principles which guided them in its construction, are extremely simple and ingenious. The known elementary substances, and the more familiar compound ones, were allowed to retain the appellations which custom had assigned them. The newly discovered elements were named after some striking property. Thus, as it was supposed that acidity was always owing to the presence of the "vital air," discovered by Priestley and Scheele, they gave it the name of oxygen, derived from two Greek words, signifying a generator of acid; and they called "inflammable air" hydrogen, from the circumstance of its entering into the composition of water.

"Compounds, of which oxygen forms a part, were called acids and oxides, according as they do or do not possess acidity. An oxide of iron or copper, signifies a combination of these metals with oxygen, which has no acid properties. The name of the acid was derived from the substance acidified by the oxygen, to which was added the termination *ic*. Thus, sulphur*ic* and carbon*ic* acids signify acid compounds of sulphur and carbon with oxygen gas. If sulphur, or any other body, should form two acids, that which contains the least quantity of oxygen is made to terminate in *ous*, as sulphur*ous* acid. The termination in *uret* was intended to denote combinations of the simple non-metallic substances,

either with one another, with a metal, or with a metallic oxide. Sulphuret and carburet of iron, for example, signify compounds of sulphur and carbon with iron. The different oxides or sulphurets of the same substance were distinguished from one another by some epithet which was commonly derived from the colour of the compound, such as the black and red oxides of iron, and the black and red sulphurets of mercury. Though this practice is still continued occasionally, it is now more customary to distinguish different degrees of oxidation by derivatives from the Greek. *Prot*oxide signifies the first degree of oxidation, *deut*oxide the second, *trit*oxide, the third, and *per*oxide the highest. The sulphurets, carburets, &c., of the same substances, are designated in a similar way. The combinations of acids with alkalis, earths, or metallic oxides, were termed salts, the names of which were so contrived as to indicate the substances contained in them. If the acidified substance contains a maximum of oxygen, the name of the salt terminates in *ate*; if a minimum, the termination *ite* is employed. Thus, sulph*ate*, phosph*ate*, and arseni*ate* of potash, are salts of sulphur*ic*, phosphor*ic*, and arsen*ic* acids; while the terms sulph*ite*, phosph*ite*, and arsen*ite* of potash, denote combinations of that alkali with sulphur*ous*, phosphor*ous*, and arseni*ous* acids. The advantages of a nomenclature, which disposes the different parts of a science in so systematic an order, and gives such powerful assistance to the memory, are incalculable. The principle has been acknowledged in all countries where chemical science is cultivated, and its minutest details have been adopted in Great Britain. It must, however, be admitted, that, in some respects, this nomenclature is defective. The erroneous idea of oxygen being the general acidifying principle, has exercised an injurious influence over the whole structure. It would have been convenient, also, to have had a different name for hydrogen. But it is now too late to attempt a change; for the confusion attending such an innovation, would more than counterbalance its advantages. The original nomenclature has, therefore, been preserved, and such additions have been made to it as the progress of the science rendered necessary. The most essential improvement has been suggested by the discovery of the laws of chemical combination. The different salts

formed of the same constituents, were formerly divided into *neutral-*, *super-*, and *sub*-salts. They were called neutral if the acid and alkali were in proportion for neutralising one another; super-salts, if the acid prevails; and sub-salts, if the alkali is in excess. The name is now regulated by the atomic constitution of the salt. If it be a compound of one equivalent of the acid, to one equivalent of the alkali, the generic name of the salt is employed without any other addition; but if two or more equivalents of the acid be attached to one of the base, or two or more equivalents of the base to one of the acid, a numeral is prefixed so as to indicate its composition. The two salts of sulphuric acid and potash are called sulphate and bi-sulphate; the first containing one equivalent of the alkali, and the second, two of the former to one of the latter. The three salts of oxalic acid and potash are termed the oxalate, *bin*-oxalate, and *quadro*-oxalate, because one equivalent of the alkali is united with one equivalent of the acid in the first, with two in the second, and four in the third salt. As the numerals which denote the equivalents of a super-salt are derived from the Latin language, Dr. Thomson proposes to employ the Greek numerals *dis, tris, tetrakis,* to signify the equivalents of an alkali in a sub-salt."

The above account of the present system of nomenclature explains the nature of the compound substances, termed acids, oxides, sulphurets, and carburets; and we will now offer a slight explanation of the distinguishing properties of acids and alkalis. Acids are compounds, capable of uniting, in definite properties, with alkaline and earthy bases; and when in a state of solution, they either have a sour taste, or redden litmus paper. Most acids contain oxygen as one of their elements, which was therefore supposed, at one time, to be the acidifying principle; but acids exist which have no trace of oxygen; and there are bodies—for instance, water—which contain a large proportion of oxygen, without possessing acid properties. Alkalis have a peculiarly pungent taste; neutralise acids; turn vegetable blues to green; change to a reddish brown the yellow colour of paper stained with turmeric; and restore the blue colour of litmus paper, reddened by the action of acids.

Minerals may be discriminated by their external and their

chemical characters, these last being determined by two kinds of analysis, the qualitative and the quantitative, the former being again divisible into examination by the blowpipe, or the dry mode, as it is sometimes called, and the action of tests and re-agents, or the humid method. Of these we shall confine our attention to the external characters, and the examination by the blowpipe, referring the student for information on those departments of the investigation which have reference to chemistry, to the works of Thomson, Brande, Turner, Fownes, &c.

Crystallisation.—The particles of liquid and gaseous bodies, during the formation of solids, sometimes cohere together in an indiscriminate manner, and give rise to shapeless masses; but they occasionally attach themselves to each other in a certain order, so as to constitute solids possessed of a regularly limited form. Such bodies are called crystals, and the process by which they are formed is termed crystallisation. Certain crystalline forms are peculiar to certain substances; and though these forms are modified to a considerable extent, yet we can invariably, by a careful dissection of the crystal, extract from it a nucleus which has constantly the same form in the same mineral species. Thus, whatever be the shape of a crystal of calcareous spar, we can always obtain from it an obtuse rhomboid; while every cube of fluor spar, by cautiously dissecting off the angles, yields for a nucleus a regular octohedron. Such a nucleus is called a primary form, while the secondary forms are deducible from the primary by certain laws of decrement. So constant are these forms, that calcareous spar never crystallises in cubes, nor fluor spar in rhomboids.

Crystallography.—A crystal may be defined to be a symmetrical mineral solid contained within plane or curved surfaces.

These surfaces are called planes, or faces, as *a*, *b*, *c* (fig. 4).

An edge is formed by the meeting of two planes, as *d*.

Crystals may sometimes be split in directions parallel to their natural planes, and frequently in other directions.

The splitting of a mineral in any direction, so as to obtain a new plane, is termed cleaving it; and the crystal is said to have a cleavage in the direction in which it splits.

The planes produced by cleaving a crystal, are termed its

cleavage planes. A plane angle is produced by the meeting of any two lines or edges.

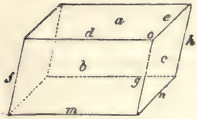


Fig. 4.

The angles *d o e*, *d o g*, fig. 4, are formed by the uniting of the lines *d o*, *o e*, and *d o*, *o g*.

A solid angle is produced by the meeting of three planes.

A plane angle is either an acute, a right, or an obtuse angle; and these will be readily understood by the following explanations and the accompanying figures:—

First describe a circle, and divide it into 360 degrees; next draw a perpendicular line *a* —— *b*, and a horizontal line *c* —— *d*, intersecting each other at the centre, and dividing the circle into four equal parts, each containing ninety degrees, fig. 5.

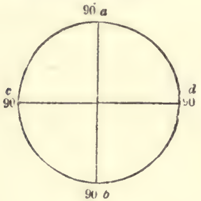


Fig. 5.

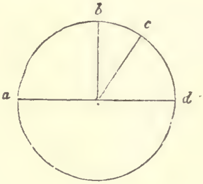


Fig. 6.

If the angle be less than ninety degrees, it is an acute angle; if ninety degrees, a right angle; if more than ninety, an obtuse angle. Thus, in fig. 6, *a* and *b* form a right angle; *b* and *c* an acute angle; *a* and *c* an obtuse angle:—or in another and perhaps simpler form, fig. 7, *a* and *b* are an acute angle; *a* and *c*, a right angle; *a* and *d*, an obtuse angle.

In fig. 4, the plane *a*, and the plane opposite, on which the object is depicted as resting, are called the summit, or the base, or the terminal plane; while the planes *b* and *c*, with those parallel to them, are termed lateral planes.

The edges of the terminal planes, as *d*, *e*, *m*, and *n*, fig. 4, are called terminal edges.

The edges *f*, *g*, and *h*, produced by the meeting of the lateral planes, are termed lateral edges.

The planes of a crystal are said to be similar when their corresponding edges are proportional, and their corresponding angles equal.

Edges are similar when they are produced by the meeting of planes, respectively similar, at equal angles.

Angles are similar when they are equal, and contained within similar edges respectively.

Solid angles are similar when they are composed of equal numbers of plane angles, of which the corresponding ones are similar.

FIG. 7.

An equilateral triangle, fig. 8, is a figure contained within three equal sides, and containing three equal angles.

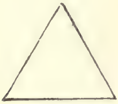


FIG. 8.

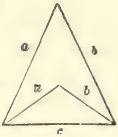


FIG. 9.

An isosceles triangle, fig. 9, has two equal sides, *a*, *b*, which may contain either a right angle, or an acute, or obtuse angle. If the contained angle be less than a right angle, it is an acute angle; if greater, it is obtuse. The line on which *c* is placed is called the base of the triangle.

A scalene triangle has three unequal sides, and contains three unequal angles.

FIG. 10.

FIG. 11.

A square, fig. 11, has four equal sides, containing four right angles.

A rectangle, fig. 12, has its adjacent sides, *a* and *b*, unequal, the four contained angles being right angles.

A rhomb, fig. 13, has four equal sides, but its adjacent angles, *a* and *b*, unequal.

FIG. 12.

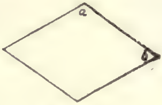


FIG. 13.

A rhomboid differs from a rhomb, in having only two, instead of four, equal sides, as fig. 14.

FIG. 14.

FIG. 15.

An oblique-angled parallelogram, fig. 15, has its opposite sides parallel, but its adjacent sides, *a* and *b*, and its adjacent angles, *c* and *d*, unequal.

When certain forms of crystals are described with reference to the rhomb, as the figure of their planes, they are termed rhombic.

A parallelopiped is any solid contained within three pairs of parallel planes.

Crystals often present the appearance of having lost their edges and solid angles, which are then said to be replaced by tangent planes. A tangent plane, with reference to an edge, signifies a plane inclined equally to the two adjacent primary planes, and parallel to the edge which it replaces; or, in plainer terms, it means cutting off the edge so evenly as to take off as much on one side as the other, as in the cube,

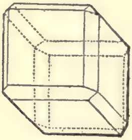


FIG. 16.

or octohedron,

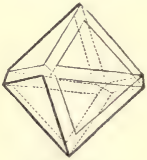


FIG. 17

and the same description applies to a solid angle.

When an angle is replaced by two such converging planes,

terminating in an edge, like that of a chisel, it is said to be bevilled.

When a solid angle is replaced by three or more converging planes, it is said to be acuminated, that is, it is replaced by planes meeting in a point.

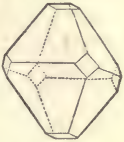


FIG. 18.

The forms of crystals are divided into primary and secondary, or derived forms. This distinction is founded on the relation of certain geometrical solids to each other; on the transition of one form to another exhibited in many minerals; on the replacement or truncation of their edges and solid angles; and on the facility with which most crystallised minerals split in certain directions; so that, however various the forms of their crystals, they may all be reduced by cleavage, into some simpler form, presenting smooth and shining faces, like the natural planes of a crystal.

To exemplify this process, the student has only to take some substance which may be cut with ease, as a piece of soap or cork, and practise these cleavages as follows: First cut the object into a cube, thus (fig. 19).

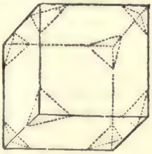


FIG. 19.

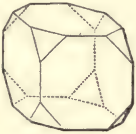


FIG. 20.

Then replace the solid angles; in plainer terms, cut off the corners, thus (fig. 20).

Continue the process (taking care to preserve the layers

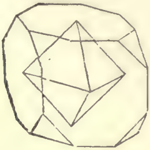


FIG. 21.

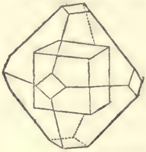


FIG. 22.

thus removed) till the planes of the cube disappear, and the octohedron will be the result (fig. 21).

Again, if the student cut off the corners of the solid angles of the octohedron (fig. 22), and continue to enlarge these planes equally till the faces of the octohedron disappear, a cube will be formed.

Or, if the twelve edges of the octohedron be replaced by tangent planes (fig. 23),

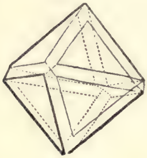


FIG. 23.

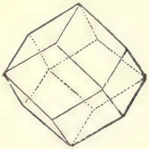


FIG. 24.

and if these be continued till they intersect, the rhombic dodecahedron will be the result (fig. 24).

By the replacement of the four alternate solid angles, or corners of the cube, till the cubic faces disappear, the tetrahedron may be formed; and by replacing all the edges of the cube with tangent planes till they intersect, the rhombic dodecahedron, fig. 24, may be produced.

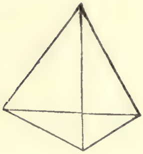


FIG. 25.

In speaking of the replacement, or cutting off the edges, or solid angles, we do not, of course, mean that these have actually been cut off; for, in fact, they never existed; but what is meant is, that the same appearances are produced, as if such truncations had actually taken place.

We have recommended the pupil to preserve the slices which he has taken off, in producing the cube from the octohedron, and the octohedron from the cube, because each of these forms being deducible from the other, he will only have to replace them to form the cube on the octohedron by addition, as the octohedron was formed from the cube by diminution; and again, after reducing the octohedron to the cube, he may form the octohedron on the cube by restoring the slices he has removed.

The secondary forms of crystals are supposed to have arisen, from the regular arrangement, on the planes of the

primary forms, of layers of crystalline matter, gradually decreasing in breadth, such layers being composed of molecules, so infinitely minute as to be invisible; so that a pyramid (fig. 26.) formed of such particles, would present on its surface, no inequality which would be perceptible to the eye.

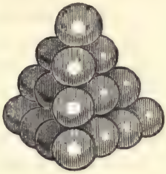


FIG. 26.

With regard to the forms of these ultimate molecules, it is known that secondary crystals may be cleaved into layers parallel to the planes of a primary nucleus of a different form, as the cube into the octohedron, as in the case of fluor, &c., while these layers may be divided by cleavage in other directions, so as to afford small bodies of determinate shape, which, divide and sub-divide them as we may, still preserve, as long as they are visible, the same form. These forms, therefore, whether cubes, octohedrons, &c., are considered as those of the component molecules of which these crystals are composed.

The arrangement of the molecules is found to be different in different forms, particularly in the case of the rhombic and pentagonal dodecahedrons. By placing a low three-sided pyramid on each plane of the regular octohedron, a rhombic dodecahedron may be formed, as (fig. 27).

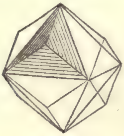


FIG. 27.

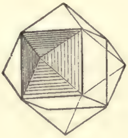


FIG. 28.

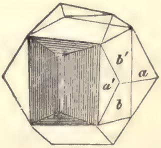


FIG. 29.

The rhombic dodecahedron may also be formed from the cube, by placing a low quadrangular pyramid on each face of the cube, as (fig. 28).

The pentagonal dodecahedron may likewise be formed on the cube, by placing, on each of its sides, an equal and similar pyramid, having two triangular and two quadrangular planes (fig. 29).

It will be seen that, in the formation of these two different dodecahedrons on the same primary form, the cube, if the molecules, as they doubtless are, be all of the same cubic form, they must be very differently arranged in the two cases; for in the rhombic dodecahedron, fig. 24, the faces are all equal, and inclined on the faces of the cube at the same angle; while in the pentagonal dodecahedron, the faces of the pyramid are only equal two and two, *a* and *a*, *b* and *b*, and are inclined on the planes of the cube at different angles. From measurements by the goniometer, and calculations carefully made, for the purpose of determining the mode of aggregation of atoms of the same shape, requisite to produce these different forms, it has been ascertained that the pyramids of the rhombic dodecahedron, fig. 24, must be composed of successive layers of molecules, each layer being of the thickness of one molecule, and each successive layer diminishing by the breadth of one molecule on each side; but that in the case of the pentagonal dodecahedron, fig. 29, the layers composing its pyramids must be of the thickness of two molecules, and must diminish in breadth unequally on the two sides; that is, on the side of the quadrangular plane *a*, they must diminish two molecules in breadth, for one in height; and on the side of the triangular plane *b*, they must diminish one molecule in breadth, for two in height, thus—(fig. 30).

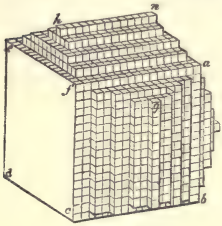


FIG. 30.

Hence, it is inferred that external form depends, as might be supposed, on internal structure, and is determined by the combination of minute particles of regular shape.

We will now submit a list of the primary forms, which, on the authority of Mr. Brookes, are supposed to be in number fifteen :—

1. The cube, contained within six square prisms (fig. 31).
2. The regular tetrahedron, contained within four equilateral triangular planes (fig. 32).
3. The regular octohedron, resembling two four-sided pyramids, set base to base. The planes are equilateral triangles; and the common base of the two pyramids, which

will hereafter be denominated the base of the octohedron, is a square (fig. 33).

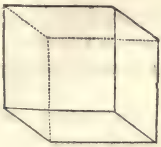


FIG. 31.

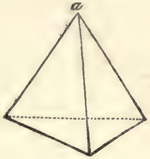


FIG. 32.

4. The rhombic dodecahedron, contained between twelve equal rhombic planes, having six solid angles, consisting each of four acute plane angles, the two opposite ones, as *a* and *b*, being sometimes called the summits, and eight solid angles or corners, consisting each of three obtuse plane angles (fig. 34).

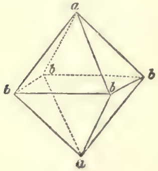


FIG. 33.

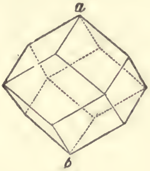


FIG. 34.

5. The octohedron with a square base, which is bounded by eight faces which are similar isosceles triangles. The base, *b*, *b*, *b*, *b*, is always a square, and is the only part of the figure which is constant (fig. 35).

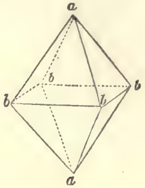


FIG. 35.

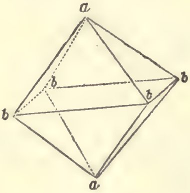


FIG. 36.

6. The rectangular octohedron, which is limited by eight

isosceles triangles. The base, *b, b, b, b*, is always a rectangle; but the ratio of its two sides is variable, as are all the other dimensions of the figure (fig. 36).

7. The rhombic octohedron is contained under eight faces, which are similar scalene triangles, while the base, *b, b, b, b*, is a rhomb. All its dimensions are variable (fig. 37).

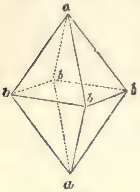


Fig. 37.

8. The right square prism, which is a six-sided figure, differing from the cube only in its four lateral planes, *c, c, c, c*, being rectangles. The extreme or terminal planes, *a, a*, are square. The term right denotes that the lateral and terminal planes are inclined to each other at a right angle. It is used in opposition to oblique, which signifies that the sides are not perpendicular, but form an oblique angle with the terminal planes (fig. 38).

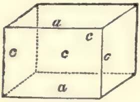


Fig. 38.

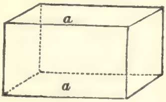


Fig. 39.

9. The right rectangular prism differs from the preceding, in the terminal planes, *a, a*, being rectangular instead of square (fig. 39).

10. The right rhombic prism differs from the preceding only in its terminal planes being rhombs (fig. 40).

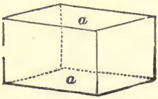


Fig. 40.

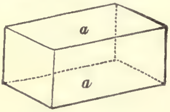


Fig. 41.

11. The right rhomboidal prism differs from the preceding form, in the terminal planes, *a, a*, being rhomboids (fig. 41).

12. The oblique rhombic prism; in this form the terminal planes, *a, a*, are rhombic, and the lateral planes form an oblique angle with them (fig. 42).

13. The oblique rhomboidal prism, sometimes called the doubly oblique prism, differs from the preceding in the terminal planes, *a*, *a*, being rhomboids (fig. 43).

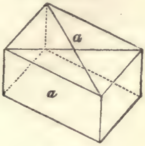


FIG. 42.

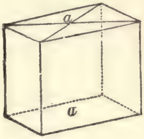


FIG. 43.

14. The rhombohedron, which is bounded by six prisms which are exactly of the same size and form (fig. 44).

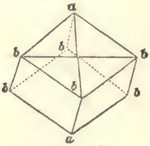


FIG. 44.

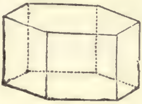


FIG. 45.

15. The regular hexagonal prism, which is bounded by six perpendicular, and two horizontal or terminal planes, which are at right angles to the former. Like the regular hexagon of geometry, the lateral planes incline to each other at angles of 120 degrees. If these angles are not of 120 degrees, the prism is irregular (fig. 45).

These are considered as the primary forms, many of which are geometrically allied to each other. Thus, as we have

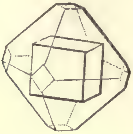


FIG. 46.

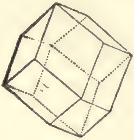


FIG. 47.

already observed, if the six solid angles of the octohedron are replaced by tangent planes, and these are enlarged till

they intersect each other, and the faces of the octohedron disappear, a perfect cube is produced (fig. 46).

If the twelve sides of the octohedron (fig. 23) are replaced by tangent planes, and these are extended till they mutually intersect, the rhombic dodecahedron will be formed (fig. 47).

The cube may, by analogous changes, be converted into the octohedron, tetrahedron, and rhombic dodecahedron. For, as previously stated, if the eight solid angles of the cube be replaced by equilateral triangles, and these are enlarged till the planes of the original cube are destroyed, the octohedron is the result.

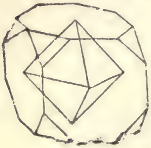


FIG. 48.

The tetrahedron may be formed by replacing the four alternate solid angles of the cube by tangent planes, so that all its original faces disappear (see fig. 32).

By replacing the twelve edges of the cube (fig. 16) with tangent planes till the new faces intersect each other, the rhombic dodecahedron will be produced (fig. 24).

The octohedron with a square base is allied to the right square prism, for if (fig. 35) two tangent planes are substituted for the solid angles, *a*, *a*, and the edges of the base are replaced by faces perpendicular to the former, new forms will result. If the faces of the octohedron disappear, the right square prism is formed (fig. 49); but if traces of them remain, secondary forms, intermediate between the two primary forms, will be produced.

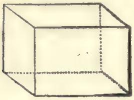


FIG. 49.

The rectangular and rhombic octohedrons, and the right rectangular and rhombic prisms, are associated with each other. Thus on replacing the solid angles *a*, *a*, and the four edges of the base of the rectangular octohedron (fig. 36), by tangent planes, and extending them till the planes of the octohedron disappear, the right rectangular prism is formed (fig. 50); and the rhombic octohedron (fig. 37), by a similar change, is converted into the right rhombic prism (fig. 51).

By applying tangent planes to all the edges of the rhombic octohedron, fig. 37, except those of the base, the rectangular octohedron, fig. 36, may be produced; and by reversing the

operation, the latter is converted into the former. In this last case, the solid angles of the rhombic octohedron must be

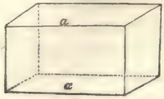


FIG. 50.

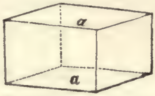


FIG. 51.

so placed as to bisect the edges of the base of the rectangular octohedron.

The rhombohedron (fig. 44) and the six-sided or hexagonal prisms (fig. 45) are allied to each other. If tangent planes are laid on the two solid angles of the rhombohedron, and the six, solid, lateral angles marked *b*, or the edges between them, are replaced by equal planes perpendicular to the former, a six-sided prism results; the six-sided prism may be reconverted into the rhombohedron, by replacing all its alternate solid angles by equal and similar rhombic planes.

The six-sided prism is often associated in nature (for instance in quartz) with a six-sided pyramid, formed by all its terminal planes, being replaced by isosceles triangles (fig. 9). If the faces of the prism disappear, the double six-sided pyramid results.

Those crystalline forms which have an intimate geometrical connexion with each other, are considered by crystallographers, as constituting certain groups, which are termed systems of crystallography.

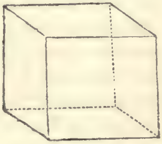


FIG. 52.

CLASSIFICATION OF MOHS. — This arrangement apportions the fifteen primary forms as follows:—

I. The Tessular system comprises the cube (fig. 52), the tetrahedron (fig. 32), the regular octohedron (fig. 33), and the rhombic dodecahedron (fig. 34).

II. The Pyramidal includes the octohedron, with a square base (fig. 35), and the right square prism (fig. 38).

III. The Prismatic comprises the rectangular octohedron (fig. 36), the rhombic octohedron (fig. 37), the right rectangular prism (fig. 39), and the right rhombic prism (fig. 40).

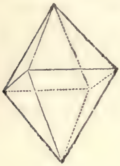


Fig. 53.

IV. The Hemi-Prismatic consists of the right rhomboidal prism (fig. 41), and the oblique rhombic prism (fig. 42).

V. The Tetarto-Prismatic is composed of the oblique rhomboidal prism (fig. 43).

VI. The Rhombohedral includes the rhombohedron (fig. 44), and the regular hexagonal prism (fig. 45).

Two or more simple forms united, constitute a combination. These combinations are of great importance in the study of crystals. They are called binary, ternary, quaternary, according to the number of simple forms combined.

The combination must be derived from the same fundamental form. They must be in such positions, with regard to each other, as are peculiar to the system to which they belong.

The edges in which the faces of two different forms contained in a combination meet, are termed edges of combination.

Discoveries of Sir David Brewster.—Such is a briet outline of the arrangement of crystalline forms by Mohs, which is extensively adopted; the distinctions of which are so far important that all the forms which a salt or other mineral substance assumes, almost always belong to the same system of classification. The justice of this mode of arrangement has been farther proved by the optical investigations of Sir David Brewster, which will be best understood by the following explanation:—

If we draw a black line on paper, and view it through a piece of Iceland spar, which is the purest variety of carbonate of lime,* the line will appear double in every position except one, in which the one line will be observed to overlap the other. In the position at right angles to that, the separa-

* See a splendid example in the collection of the British Museum, case 43.

tion of the two lines is the greatest possible. The overlapping takes place in what is called the principal section of the crystal, and the greatest separation occurs in a plane very nearly coinciding with the equator of double refraction, which is a plane at right angles to the crystallographic axis of the rhomboid.

If we cut off the summits of the rhomboid, and polish the new faces, we shall find, that a pencil of light transmitted through these new faces is not divided into two. The line along which there is no double image, is named the axis of double refraction, or the optic axis.

This discovery confirms, in a very important degree, the correctness of the arrangement proposed by Mohs. Sir D. Brewster has ascertained that all minerals belonging to the same system are connected by intimate optical relations; for instance, that all those which belong to the rhombohedral and pyramidal systems, have only one axis of double refraction, which is coincident with the axis of symmetry of the crystal; that all minerals belonging to the prismatic system, and its subordinates, have two axes of double refraction; while all belonging to the tessular system have either three axes *in equilibrio*, or are otherwise so constituted with reference to this property, that they do not display any double refraction at all.

The above imperfect sketch will suffice to show that crystallography is an extremely interesting and instructive study, and one which can by no means be omitted in an account of the external characters of minerals. At the same time it cannot be denied, that however valuable or attractive to the experienced mineralogist, it is of little practical use in furnishing a guide for distinguishing minerals. This is especially the case as regards the beginner and the practical geologist. Comparatively few minerals occur in the state of regular crystals; they are met with, either massive or so imperfectly crystallised, that the student is compelled to have recourse to other characters, which, when united, are more obvious, though singly they may be less so than that afforded by the measuring of crystals. Crystallography, it may be said, is to mineralogy what mathematics is to calculation; while the general characters of minerals may be considered as representing the arithmetic

of the science; the former being essential to a complete acquaintance with the subject; while the latter is indispensable for acquiring a general knowledge of the same.

EXTERNAL CHARACTERS OF MINERALS.—The next step in the progress of the student will be to render himself acquainted with the external characters of minerals; and, with the view of studying these and the practical details of the science, it is essential that he should possess a properly arranged collection; and, if possible, that he should avail himself of the assistance of a well-qualified instructor; since more may be learned in a few lessons from such a person, than can possibly be gathered from books in a lengthened period. Mr. Heuland, Mr. Sowerby, Mr. Stutchbury, and Mr. Tennant, are in the habit of furnishing such collections. They are likewise supplied by Mr. Abel, of Hamburgh, and Mr. Krantz, of Berlin. The specimens comprising such a cabinet need not be either large, showy, or expensive; they should be arranged according to the system of Phillips; and, with the exception of some of the more rare specimens, should comprise the substances enumerated at the close of Phillips's Introduction, (Allan's edition, page lxxx.) It will also be necessary to procure another collection in fragments, prepared expressly for analysis and fusion by the blowpipe. The works required will be few; that of Phillips should form the text-book; Berzelius on the Blowpipe, Griffin's Treatise on the Blowpipe; Sowerby's British Mineralogy may also be consulted with advantage. The copy of Phillips should be bound with blank leaves, for the purpose of taking notes of the specimens composing the collection of the student, the lessons of his instructor, and the general knowledge which he himself acquires. His specimens should all be registered on the blank pages, so as to point out their proper place in the drawer; thus $\frac{6}{14}$ may indicate that a certain mineral is placed as the fourteenth object in the sixth drawer. The student should also possess a set of models of crystalline forms, which can be procured from the parties above-named.

In addition to his own cabinet, he should farther avail himself of the various public stores within his reach; the splendid collection of the British Museum may be consulted with eminent advantage by the aid of the Synopsis.

The reflecting goniometer will be found indispensable for

correctly measuring the angles of crystals, and, as in the instance of augite and hornblende, for distinguishing several which present considerable similarity to each other. The use of the instrument is not particularly difficult, and the student is referred to Phillips, fourth edition, Introduction, p. xxxii, for directions, the observance of which will speedily enable him to attain the management of it with ease and success.

In studying the characters of minerals according to the arrangement of Phillips, the student should commence by a careful and attentive perusal of the admirable Introduction from page xiii to page lxviii. The various external characters detailed in page xviii should be the object of especial study, more particularly those enumerated in the first column in the following list; and the chapter on Structure, above all, cannot be too firmly impressed on the mind.

They are as follow:—

External form	Transparency
Structure	Lustre
Fracture	Colour
Frangibility	Flexibility
Hardness	Double refraction
Streak	Touch, taste, and odour
Magnetism	Powder
Electricity	Adhesion to the tongue
Specific gravity	Phosphorescence.

Cleavage.—It may be necessary to add a few remarks on this subject, which is not particularly dwelt on in the work of Phillips. It means the indications of the faces of the primary crystal, or at least of some of them. There are several minerals which possess cleavage so perfect, that they at once exhibit the crystalline faces, by splitting into fragments, having each the crystalline shape of the mineral; as calcareous spar, which breaks into rhomboids, and galena, which divides into cubes. Other minerals require more care; sometimes the natural joint may be seen by turning the crystal round in a strong light; and by the application of a chisel, or a small knife, it may be cleaved in those directions; or it may be split by means of a pair of small cutting pincers, whose edges are parallel. A small, short chisel, fixed, with its edge outward, in a block of wood, is a convenient

instrument on which to rest a mineral which we are desirous of cleaving. Minerals, sometimes, cleave only in one direction, as mica; sometimes in two, three, or four. As some practice is requisite, it will be expedient to commence with a facile substance, as carbonate of lime, or galena, and proceed to others more complicated and refractory.

When the student has gone through this preliminary course of reading, he may enter on the practical examination of his collection. In so doing, he will find it expedient to confine his attention to a few objects at once; and a single genus, if somewhat extensive, as, for instance, quartz, will afford ample study for the first few lessons.

USE OF THE BLOWPIPE.—Having become acquainted with the laws of crystalline form, and the system of crystallography, most generally adopted, as well as with the general characters of minerals, the student should next examine them by means of the blowpipe. His text-book for this purpose should be a cheap and unpretending little work;* by the guidance of which he will not only acquire the use of that instrument with little trouble, but will soon have no difficulty in satisfying himself of the name and properties of any mineral which may fall in his way. Another work, by the same author, entitled "Chemical Recreations," contains some useful tables of the phenomena presented by minerals before the blowpipe, the colour of their beads when fused with the various fluxes, &c., &c. The directions contained in these treatises are so simple and judicious, that we shall at once refer to them for farther particulars, and content ourselves with a very few practical observations.

In the first place, we have ever found the most simple blowpipe to be the best: the common curved brass instrument used by jewellers, without a bulb, is what we prefer; and of these we should recommend two, one with a small orifice for the inner, and one with a larger for the outer flame. With reference to the use of the instrument, our own experience tends to convince us that the difficulty of employing it is much exaggerated. We add, however, the following directions for those who may require them:—

The great object is to maintain an equal and steady

* Griffin's Treatise on the Use of the Blowpipe.

stream of air, as long as is required. To effect this, the beginner should first learn to breathe through the nostrils, keeping the mouth shut; next let him distend the cheeks with the air thus inhaled, and make several respirations without allowing the air to escape from his mouth; when able to effect this, let him put a blowpipe between his lips, and filling his mouth with air, expel it, gently and steadily, by the action of the cheeks, while he breathes by his nostrils, applying the tongue to the palate, so as to interrupt, in some degree, the communication between the mouth and the nostrils. As the air in the mouth becomes exhausted, it may be renewed by withdrawing the tongue from the palate, and replacing it again, as in pronouncing the syllable *tut*. Let him first practise this with the blowpipe alone, without applying it to a flame at all; next let him try to keep up a flame without directing it to any object; and lastly, let him attempt to oxidise some of the metals, to reduce some of the most facile ores, and to fuse some of the most fusible earthy substances. Bismuth or galena will answer to begin with; and after practising with a few others, he may attempt the various substances in the order prescribed in the treatise of Mr. Griffin.

As regards the flame, we should advise him to commence with a candle: one of a substantial size and large wick is to be preferred; such as are called shoemakers' candles, with double wicks, are extremely well adapted for the purpose. As the candle, however, is apt to gutter from the heat of the charcoal on which the mineral requires to be placed, the student as he advances may use a tinned lamp, which may be fed with oil, tallow, or naphtha. Alcohol is best, as being clearest, and giving no smoke, but it is the most expensive. The wick of the lamp or candle, it may be added, should be divided, to give a greater extent of flame, and should be bent in the direction of the object to be examined. The orifice of the blowpipe should be held about the tenth of an inch above the bent wick, and the air should be impelled along the wick without touching it. The operator should place the candle in such a position as to be able to rest both elbows on the table. It may be necessary to add, that a gentle aud steady blast is quite sufficient, and that beginners commonly blow with too much violence.

Should the student still find a difficulty in using the instrument, he has only to apply to the first working-jeweller at hand, for full instructions on the subject.

The blowpipe is usually placed in two different positions with reference to the flame, which will be best explained by the following figures. The first represents the outer, or oxidating flame (fig. 54).

To produce this, it is necessary to use the blowpipe with the larger orifice, and to insert it about the tenth of an inch into the flame, and about the same distance above the wick, while the assay, which is supported on a platinum hook, is held at the point of the flame.

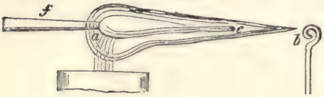


FIG. 54.

The inner or reducing flame is managed as follows: the blowpipe should have a smaller orifice than that employed for the outer, or oxidating flame; it is necessary to blow a little stronger than in the first experiment, and the position of the assay should be such that it is surrounded by flame (fig. 55).

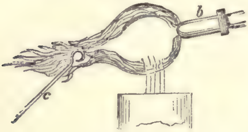


FIG. 55.

The small fragment of mineral submitted for examination to the blowpipe is called the assay; and with respect to size, the beginner should not attempt a piece larger than a grain of mustard-seed. It is a common fault to commence with specimens which are too large. It ought, if possible, to be chipped off, in the shape of a small scale, with a sharp edge, or point, because these points are more easily acted on than those which are thicker; and in proportion as the point becomes rounded, or retains it sharpness, it may be considered fusible or infusible. Next take a piece of charcoal, (that prepared from alder is best,) and, with a borer made for the purpose, make a neat little hole about the eighth of an inch deep, and the fourth of an inch wide, and situate between the centre and the edge of the piece of charcoal. It will be expedient to saw the charcoal into sticks an inch square, and to support them on a piece of tin, bent at the end to hold them firmly.

The preparatory operation, termed roasting, or calcining, consists in submitting the metallic arseniurets, sulphurets, and other substances, to a low, red heat; the supports, that is the substances on which it is placed, being either charcoal, mica, the open glass tube, or the tube with a bulb at the end, called the glass matrass (fig. 56).

FIG. 56.

Unless this operation be carefully performed, so as to expel all the sulphur or other volatile matter, it will be found impossible to reduce the ore with any satisfactory result.

Fluxes are substances added to metallic ores, or other minerals, in order to promote their fusion. The most useful of these are borate of soda, or borax; carbonate of soda, and microcosmic salt, which should be procured pure, and kept in phials.

The mode of proceeding with the fragment of a mineral to be examined by the blowpipe is this:—First, heat it gently in the glass matrass, observing whether it give off water, change colour, decrepitate, give off volatile matter, and whether such matter be sulphur, known by its peculiar odour; arsenic, which in smell resembles garlic; selenium, which gives an odour resembling decayed horseradish; or mercury, which is known by its peculiar appearance.

The next step, will be to heat another fragment of the same mineral, without fluxes, on charcoal; observing whether, on being gently heated in the outer flame, it gives off volatile matter, and whether such matter be sulphur, arsenic, or selenium, &c.; whether it decrepitate, become magnetic, fuse, and whether such fusion be complete, partial, quick, or slow; with a pasty aspect, or with the appearance of a liquid; whether it intumesce, and that slightly or violently; whether it volatilise; whether it give off fumes, and whether they be copious or slight, and of what colour; whether they leave a remainder or not, and whether they condense or not on the support. It is also to be observed, whether the assay colour the jet; burn either with or without a flame; change colour once, or more than once; whether it become absorbed by the charcoal; whether it fuse with a result, and whether such result be a bead of metal, or ashes, or powder; a glassy globule, or a white enamel; whether the

glass be transparent, or filled with air-bubbles; coloured or colourless; homogeneous or heterogeneous; and whether the enamel be smooth, or have the appearance of a frit, or whether it be homogeneous or heterogeneous.

A fragment of the mineral well roasted, to drive off all metallic matters, is then to be heated with the different fluxes, and the results noted, observing all the particulars above enumerated. The order in which the different appearances take place must likewise be noticed, and whether they occur on the first application of heat, or after a long exposure to its action. For earthy minerals, charcoal is not a convenient support; they may be first dried in the matrass; and then a small scale held in the forceps is to be heated, first in the outer flame, then in the inner, in order to try its fusibility. If it should prove refractory after a long application of the inner flame, and if no appearance of roundness on the point or edges of a minute scale or splinter can be discovered through a lens, it may be considered infusible by itself, and may then be heated with soda, on platinum foil, or wire. By this process, fusion will be effected, and the tinge imparted to the glass thus produced will indicate the metallic oxide, which forms the colouring matter of the mineral.

CLASSIFICATION OF MINERALS.—Mr. Griffin divides minerals into four classes, according to the phenomena which they present when exposed to the action of the blowpipe, and other characters easily ascertained.

The classes comprise—

1 Combustible minerals.	3 Earthy minerals.
2 Metallic minerals.	4 Saline minerals.

1. The combustible minerals are distinguished by the following characteristics.

They are of low specific gravity, generally below 2·0, water being as 1·0; none, with the exception of the diamond, being above 2·5, and some so light as to float on water.

They are all (with the exception of the diamond) soft, yielding easily to the knife; some are liquid.

Some of them are highly combustible, at or below a red heat. The rest are all, more or less, combustible by the action of the blowpipe; even the diamond is slowly combustible at a less heat than is required to melt silver

2. The characteristics of the second class, the metallic minerals, are,

Specific gravity exceeding 5·0.
Lustre metallic when scraped.

These are in the metallic state.

Or specific gravity less than 5·0, but more than 2·5, and they are destitute of the metallic lustre, but they are

Reducible to the metallic state by the blowpipe, or
Rendered magnetic, or
They volatilise wholly, or in part, producing a vapour, or
Communicate a colour to borax.

Some of the substances of this class are combustible, but their specific gravity greatly exceeds that of the combustible minerals of class 1.

3. The earthy minerals are characterised as follow:—

Insoluble in water.
Tasteless.
Incombustible at a white heat.
Specific gravity less than 5·0.

They are farther destitute of true metallic lustre when scraped; are not reducible to the metallic state; nor do they volatilise at a high temperature before the blowpipe.

4. The saline minerals are

Soluble in water, and
Impart a sapid taste.

These classes are divided into orders, and some of the orders into genera, and the genera again into families.

The first class is divided into two orders, characterised by their burning with a flame, or without it.

The second class is also divided into two orders, the characteristics of which are volatilising, or not volatilising. The first order is divided into genera, distinguished, the first, by volatilising wholly; the second, by leaving a residue reducible to the metallic state with borax; and the third, a residue not so reducible.

The characteristics of the families, into which the genera of the first order are divided, are the absence or presence of the metallic lustre.

The characters of the genera of the second order are, the being, or not being, reducible to the metallic state, either with or without borax. The families are distinguished by

the absence or presence of the metallic lustre; or by the assay becoming, or not becoming, magnetic after roasting.

The third class, the earthy minerals, are divided into three orders:—First, those that are soluble, wholly, or in considerable proportion, in cold, diluted muriatic acid. Secondly, those fusible before the blowpipe. Thirdly those infusible. The first order is not divided into genera and families. The second and third orders are divided into several genera, the characteristics of which are their different degrees of hardness; and these degrees of hardness are characterised by the minerals, first, scratching quartz with ease; secondly, scratching quartz with some difficulty, and scratching feldspar with ease; thirdly, being as hard, or harder, than feldspar; being scratched by quartz, and scratching window glass with ease; fourthly, being softer than feldspar; scratching fluor, and scratching window glass feebly; fifthly, being scratched by fluor spar.

The fourth class, or the saline minerals, are divided into two orders, the characteristics of which are, the giving or not giving, when in solution, a precipitate with carbonated alkali. These orders are not divided into genera and families, the minerals composing them being few and easily distinguished.

By pursuing the various branches of inquiry which we have thus pointed out, by studying first, the principles of crystallography; next, the external characters of minerals; and by directing his attention, lastly, to their chemical relations, the student will, by insensible degrees, acquire a highly valuable acquaintance with this interesting science, and will soon be able to effect the essential objects of identifying the various mineral substances submitted to his inspection, and of connecting their occurrence with the respective deposits in which they are found with the general structure and past history of the earth. In short, he will speedily be enabled to acquire a sufficient knowledge of the subject for every purpose of geological investigation.

EXERCISES

ON CRYSTALLINE FORMS.

1. Let the student take a piece of soap, or of cork, and cut it into a form resembling fig. 19, he will produce a cube, and will thus form the first geometrical figure in the series.

2. Cut off the corners regularly and evenly, so as to leave a neat little triangle at each corner, he will thus have replaced the solid angles by triangular planes (fig. 20).

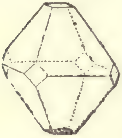


Fig. 57.

3. Continue cutting off the corners till the faces of the cube disappear, and he will effect another modification; the cube will be changed to the octohedron (fig. 21).

4. Cut off the corners of the octohedron, and you will produce figure (fig. 57). And if you continue these cuttings till the faces of the octohedron disappear, a cube will again be formed (fig. 22).

5. Form a cube a second time, and cut away its four alternate corners, till the faces of the cube are destroyed, and you will form a tetrahedron (fig. 32).

6. Form a cube a third time, and cut off its edges evenly and neatly, so as to take off as much on one side as the other, you will have replaced the edges of a cube by tangent planes, as figs. 16 and 32.

7. Continue these cuttings till they intersect, and the rhombic dodecahedron will again be produced (fig. 34).

8. Form an octohedron, and cut off its twelve edges in a like even manner, and you will likewise replace its edges by tangent planes (fig. 17).

9. Continue these cuttings till they touch each other, and you will again produce the rhombic dodecahedron (fig. 34).

10. Form a cube for the following purpose. Cut off the corners very carefully and regularly, and as carefully lay the slices aside till you have formed the octohedron. Then

replace the slices on the octohedron, till you restore it to a cube (figs. 21 and 48).

11. Form an octohedron for the like purpose, reduce it to a cube, and, by replacing the slices, restore it to an octohedron (fig. 33).

12. Commit to memory the names of the fifteen primary forms, page 92, *et seq.*; study their characteristic differences, as well as their geometrical relations; copy their outlines on tracing paper, and study them by the assistance of a series of models.

13. Describe their appropriation in the system of Mohs.

EXERCISES

ON THE GENERAL CHARACTERS OF MINERALS.

1. We would here repeat the recommendation to commence reading with much care the Introduction to Phillips's Mineralogy, and to devote peculiar attention to the chapter on structure, as well as to the various sections which treat of external form, fracture, hardness, double refraction, and specific gravity.

2. Commit to memory the divisions of mineral substances, as enumerated by Phillips and Griffin, and learn the chief types of each class.

3. There are some half-dozen different substances which, from their occasional resemblance to each other, should be studied with peculiar assiduity; and the pupil should accustom himself, both in theory and practice, to distinguish between them, both as single minerals, and in their combination in rocks. These are quartz, carbonate of lime, hornstone, feldspar, augite, and hornblende. With a view to this object—

4. Describe quartz under its general physical characters of mineral composition, hardness, fusibility, forms and localities of occurrence, crystalline form, and different species and varieties

5. Ascertain in what respects quartz differs from crystallised carbonate of lime, and what are its best distinguishing characters.

6. Describe carbonate of lime under the heads specified above, and repeat in what particulars it is distinguishable from quartz.

7. Describe, in a similar manner, hornstone and feldspar, and state the points of distinction between such varieties of these substances as resemble each other.

8. Describe augite and hornblende, and state their distinctive characters.

9. Pay particular attention to the following mineral substances, as being of frequent geological occurrence, viz., mica, talc, clinkstone, claystone, chlorite, actinolite, hypersthene, diallage, serpentine, steatite, jasper, porphyry, basalt, carbonate of magnesia, bitterspar, dolomite, sulphate of lime, bitumen, oxide of iron, sulphuret of iron, iron and copper pyrites, schorl, garnet, and chiastolite.

10. Commit to memory the names of those minerals which represent the scale of hardness.

11. Select various sets, comprising each some half-dozen familiar substances, and describe their principal characters, as primary form, fracture, colour, transparency, hardness, action of acids, action of blowpipe, &c. &c.

12. Write out a list of crystalline forms, and copy, on tracing paper, the outlines of such as are most familiar and of frequent occurrence.

13. Copy and commit to memory a list of the zeolites, enumerating their principal varieties and distinctive characters.

14. In exemplifying the above instances, the student should be careful to unite practice with theory, and to compare every substance with specimens from his own cabinet, with the view to realise the features of the descriptions which he finds in books.

15. After a short period, he may place before himself a drawer filled with various but allied species of minerals, and endeavour to ascertain the names and characters of each.

16. When further advanced, he may place before himself a collection of heterogeneous kinds and endeavour to identify their names and varieties.

17. At a more mature period he may disarrange the whole collection, and endeavour to restore each specimen to its place.

CHAPTER VI.

PHYSICAL GEOLOGY.

Authors :— Hutton, Playfair, M'Culloch, Bakewell, Lyell, Murchison, Delabeche, &c., &c.

Museums :—Geological Society, Museum of Economic Geology.

Having furnished elementary information, respecting the substances composing rocks, we now proceed to give an outline of the nature and classification of the rocks themselves. The most comprehensive arrangement which the student can form, is by reducing them to that fourfold division, under which they may be classed as follows :—

I. After penetrating through the vegetable mould, or alluvium, or drift, or other superficial deposit, the underlying rock, at certain points, is found to be a substance of crystalline, or glassy texture, consisting of one or other of the plutonic or unstratified rocks, comprising granite, with its associate deposits of syenite, greenstone, hypersthene rock, diallage rock, and serpentine; or one of the trap rocks, including basalt, porphyry, clinkstone, claystone, compact feldspar, pitchstone, &c., &c., which are all characterised by two distinctive features—the absence of stratification and of organic remains.

II. In other localities the crust of the earth is formed of volcanic rocks, comprising the lavas, trachytes, basalts, greystones, obsidian, pumice, tufa, &c., the ejection of modern volcanoes.

III. In other places we meet, in the same relative position, with the metamorphic or altered rocks, or primary strata, as they are variously styled, which are conceived

to be sedimentary deposits, altered by heat; resembling the plutonic or unstratified rocks in being destitute of fossils, but differing from them in presenting marks of stratification.

IV. At other points we find, in similar situations, the aqueous or fossiliferous strata, characterised by stratification and the presence of fossils.

Arrangement of Deposits.—At an earlier period of the science, the arrangement and nomenclature of the rocks, with reference to their order and succession, were determined as follows:—

The plutonic and metamorphic rocks bore the general name of primitive, it being supposed that they were formed before all others. The deposits lying immediately above them, from resembling the schistose rocks below, in their crystalline texture, while they bore a similarity to the sedimentary substances above, in exhibiting proofs of mechanical origin, and containing organic remains, were conceived to form an intermediate class, and the name of transition rocks was accordingly employed to distinguish them. The succeeding strata, up to the chalk, were termed secondary, and all above the chalk were named tertiary formations. The progress of geological inquiry, however, soon brought facts to light which produced a considerable change in this nomenclature. It was found that the so-called primitive rocks were, in fact, of various ages; that some had been erupted as late as the close of the secondary, and others during the tertiary period, having penetrated and altered strata of that date. That the so-termed transition strata were, in like manner, of various geological dates and characters, and the result has been the adoption of the arrangement now generally received, by which the primitive rocks, as they were previously termed, are distinguished as plutonic, or unstratified, and metamorphic, or stratified; while the term transition is virtually abolished, and the whole series of fossiliferous deposits, from the earliest up to the chalk, are termed secondary; the inferior beds up to the carboniferous series being sometimes styled the lower; those from the carboniferous system to the oolite, the middle; and the wealden and chalk, the upper; the strata which overlie the chalk being named tertiary; while the loose and super-

ficial beds of sand, loam, and gravel, are denominated modern alluvium; and, as these last in some districts are strewed with boulders and masses of primary rock, such deposits with some others are termed ancient alluvium; the beds of gravel, &c., being supposed to be the result of agencies still in operation, while the drift and boulders are regarded as the effect of violent floods or inundations which have ceased to act on our globe. These subjects of drift, or till, as it is locally termed, and erratic blocks or boulders, have recently engaged considerable attention, and an opinion is fast gaining ground that the erratic substances in question are the results of an agent now in operation, and that they have been transported by icebergs which, on melting, have deposited them at the bottom of the then existing sea. M. Agassiz has suggested the glacial theory, to account for these deposits; but this hypothesis is scarcely received with so much favour as the preceding; while, in either case, the introduction of ice, as a moving power, constitutes a new and striking feature in geological inquiry.

ARRANGEMENT OF THE STRATA.

FOSSILIFEROUS DEPOSITS.

The following table will convey a general idea of the various formations, as regards their distinctive features of succession, mineral composition, and fossil remains:—

I. Alluvium, modern and ancient; the term *modern* being applied to the deposits now in course of formation, or appertaining to the historic period, comprising beds of rivers, lakes, peat-bogs, coral-limestones, volcanic ejections, calcareous deposits from mineral springs, &c., containing the remains and the works of man; the term *ancient* being usually bestowed on like accumulations formed prior to the historic era, and containing no vestiges of the human race.

THE TERTIARY STRATA.

II. A vast accumulation of various deposits, marine, lacustrine, fluviatile, and volcanic, containing marine exuviæ, shells of the lake, river, and land; plants and remains of mammalia of extinct and existing species.

SECONDARY STRATA.

III. The Cretaceous Group.—A marine series of deposits, including strata of limestone, sandstone, marl, and clay, abounding in marine organic remains, as plants, corals, echinodermata, mollusca, crustacea, and fish, with turtles and reptiles.

IV. The Wealden Group.—An intercalation of fluviatile strata, between the lower greensand and the oolites, being the delta of an ancient river, and comprising beds of sandstones, limestones, and clays; containing land-plants, fresh-water mollusca, and fish; tortoises, turtles, crocodiles, and enormous reptiles, the iguanodon, hylæosaurus, cetiosaurus, and megalosaurus.

V. The Oolitic Group.—A series of marine strata, of enormous extent; comprising limestones, sandstones, and clays, replete with corals, shells, fish, and reptiles, terrestrial plants, and species of mammalia.

VI. The Lias.—A group of marine argillaceous limestones, marls, shales, and clays, with marine mollusca, crinoidea, and fishes; wood and plants, and enormous reptiles, chiefly of the genera ichthyosaurus and plesiosaurus.

VII. The New Red Sandstone Group.—A marine formation, including marls, sandstones, limestones, and conglomerates frequently of red, and occasionally of variegated hues, containing gypsum and rock-salt, with corals, mollusca, plants, fish, and reptiles.

VIII. The Carboniferous Group.—Consisting of shales, clays, ironstone, sandstone, millstone-grit, and limestone, interstratified with seams of coal, containing fresh water, and marine mollusca and fish, and innumerable remains of terrestrial and aquatic plants of tropical types, but of extinct

genera and species. The mountain limestone, with some beds of shales, sandstones, and imperfect coal.

IX. The Devonian Group.—A marine formation; consisting of red and green marls, concretionary limestones, called cornstones, conglomerate, tilestone, micaceous and grey sandstones, green slates, and sandstone, and blue crystalline limestone, containing corals, mollusca, and fish.

X. The Silurian Group.—An extensive series of marine deposits; comprising limestones, sandstones, grits, flag-stones, shales, and slates, containing corals, mollusca, crustacea (trilobites), and fish.

XI. The Cambrian Group.—A marine formation, comprising vast beds of slate rocks, with dark-coloured limestones, and sandstones, containing two or three species of corals, and of brachiopodous mollusca.

XII. The Cumbrian Group.—A like extensive series of deposits, obviously of sedimentary origin, but in which no organic remains have been discovered.

THE PRIMARY STRATA.

XIII. The Mica-schist.—Composed of mica and quartz, interlaminated so as to present the appearance of stratification, but containing no organic remains.

XIV. The Gneiss.—Formed of the component parts of granite; mica, quartz, and feldspar, fine-grained and laminated, so as to present the appearance of having been produced by the abrasion of granite, and then deposited in water. Both the gneiss and mica-schist are supposed to have been altered by heat, subsequently to their deposition.

THE PLUTONIC, OR UNSTRATIFIED PRIMARY ROCKS.

XV. The Granite and Trappean Rocks.—Comprising granite, syenite, greenstone, hornblende, diallage, serpentine, &c.; together with basalt, porphyry, clinkstone, claystone, and the trap rocks, the whole being alike destitute of stratification and of organic remains.

The relative thickness of each of these several deposits

has been estimated as below; but the statement must be regarded only as an approximation to the truth; the probability is that, with reference to the lower beds, the thickness is much greater than is here mentioned:—

	Feet.
Tertiary System	2,000
Cretaceous	1,100
Wealden	1,000
Oolite and Lias	2,500
Saliferous	2,000
Carboniferous	10,000
Old Red Sandstone	10,000
Silurian	7,500
Cambrian	20,000
Cumbrian, at least	10,000

Primary, unascertained, but far exceeding that of any of the superposed deposits.

The annexed TABLE exhibits a classification of the STRATIFIED FOSSILIFEROUS ROCKS, in a descending order as they occur in England. Each period is divided into groups, and each group into subordinate stages; each stage is characterised by a Fauna and a Flora that is special to it.

STRATIFIED FOSSILIFEROUS ROCKS.

TERTIARY PERIOD (Cainozoic Series, *Phillips*).

Superior Order, (*Conybeare*) .	Recent Group . .	Travertin Peat Shell, Marl, &c.
	Pleistocene Group, Erratic block period,	Marine beds Freshwater beds
	Pleiocene Group .	Mammaliferous Crag
	Miocene Group . .	Red Crag Coralline Crag
	Eocene Group . .	Fluvio-Marine beds Bagshot Sands Barton and Bracklesham Sands Bognor Rocks.

Secondary Period (Mesozoic Series, *Phillips*).

Super-Medial Order, (*Conybeare*)	Cretaceous Group	Upper Chalk Lower Chalk Upper Greensand Gault Lower Greensand Speeton Clay ?
	Wealden Group	Weald Clay Hastings Sands Purbeck beds
	Oolitic Group	*Upper.* Portland beds Kimmeridge Clay *Middle.* Upper Calcareous Grit—Coral Rag Lower Calcareous Grit—Oxford Clay Kelloway Rock *Lower.* Cornbrash Forest Marble Bradford Clay Bath Oolite Fuller's Earth Inferior Oolite *Lias.* Upper Lias Marlstone Lower Lias
	Triassic Group	Variegated Marls Muschel Kalk (wanting in England) Variegated Sandstone.

Primary Period (Palæozoic Series, *Phillips*).

	Permian Group	Magnesian Limestone Lower Red Sandstone
Medial Order, (*Conybeare*)	Carboniferous Group	Coal Measures Millstone Grit Mountain Limestone

Sub-Medial Order, (*Conybeare*)	Devonian Group	Conglomerate and Sandstone Cornstone and Marl Tilestone
	Silurian Group	*Upper.* Upper Ludlow Rock Aymestry Limestone Lower Ludlow Rock Wenlock Limestone Wenlock Shale *Lower.* Caradoc Sandstone Llandeilo Flags.
	Cambrian Group	Slate Rocks of North Wales, Cumberland, Westmoreland, &c.

STRATIFIED NON-FOSSILIFEROUS ROCKS.

Inferior Order, (*Conybeare*)	Metamorphic Group	Clay Slate Talcose Slate Mica Slate Hornblende Slate Gneiss

IGNEOUS ROCKS.

Unstratified Rocks	Volcanic Group	Basalt Greenstone Claystone Trachyte Porphyry Amygdaloid Lava, &c. &c.
	Plutonic Group	Granite Syenite Eurite Pegmatite.

*** This Table is adopted, with slight modifications, from Mr. TENNANT'S "British Fossils."

GEOLOGICAL DEPOSITS OF GREAT BRITAIN.—The student should trace each separate group on a geological map of the British Isles.

To commence with the most recent, the tertiary system.

we find these deposits occurring in the Isle of Wight, and the adjacent counties of Hampshire and Dorsetshire; they appear in the metropolis and its vicinity, the valley of the Thames, comprising the county of Middlesex, with portions of Essex, Kent, Surrey, and Sussex; they re-appear in the crag of Norfolk and Suffolk, and are traced in Yorkshire, and in part of Scotland. The chalk succeeds, occupying portions of Sussex, Surrey, Kent, Hants, Dorset, Wilts; and dipping under the valley of the Thames, occurs north of London, in the counties of Hertford, Bedford, Buckingham, Oxford, Norfolk, Lincoln, and York. The local deposits of the weald fill up the interval between the chalk hills of Surrey and Sussex, known as the North and South Downs, and appear, to a slight extent, in Wiltshire. The oolite group follows, commencing at the Isle of Portland, it pursues a winding course through the centre of England, from the south-eastern to the north-western shores; proceeding through the counties of Dorset, Wilts, Berks, Gloucester, Oxford, Rutland, Northampton, Lincoln, and York, where it terminates in the vicinity of Scarborough. The lias succeeds in order, and commencing at Lyme Regis, follows a similar and uneven course, in the same direction, through the counties of Dorset, Wilts, Berks, Somerset, Gloucester, Warwick, Leicester, Nottingham, and Lincoln, into Yorkshire, where it is traced to the sea-coast, and the cliffs of Redcar, near the mouth of the Tees. The new red sandstone commences in the vicinity of Exeter, and pursues a similar direction through the midland districts; traverses the counties of Devon, Somerset, Warwick, Stafford, Nottingham, Lancashire, Cheshire, and Cumberland, where it gives place to slaty rocks, of older date. The magnesian limestone, an associate deposit, is developed from the Trent to the Tyne, in the counties of Nottingham, Shropshire, York, Westmoreland, and Durham. The coal formation follows no regular course, but is distributed in local areas, called basins. The principal, commencing with the south, are those of Somersetshire, Gloucestershire, North and South Wales, Worcestershire, Staffordshire, Warwickshire, Leicestershire, Derbyshire, Nottinghamshire, Lancashire, Yorkshire, Cumberland, Durham, and Northumberland; and in Scotland, those of the Forth and

Clyde, with others in various parts of Ireland. The Devonian group is developed in Devonshire, Herefordshire, Monmouthshire, and Shropshire; and in Caithness, Cromarty, and other parts of Scotland. The Silurian group occurs in Gloucestershire, Worcestershire, Staffordshire, Herefordshire, Shropshire, Radnorshire, Montgomeryshire, Caermarthenshire, Brecknockshire, Pembrokeshire, and Monmouthshire. The Cambrian and Cumbrian systems consist of masses of sub-crystalline and slaty rocks developed in Cumberland and in Wales, and the mica-schist, gneiss and granite formations occur in the Highlands and Western Isles of Scotland, and in Ireland; the whole series forming, with one or two trifling omissions, a complete epitome of the physical geology of the earth, in the comparatively limited extent of a few hundred miles.

Plutonic Rocks.—Granite.—Granite is a compound, crystalline rock, composed of crystals of mica, quartz, and feldspar, aggregated together, and separable by mechanical means. The mineral which generally predominates is feldspar; it is most commonly dark red, or white; quartz is the prevailing substance next to feldspar, and has a proportionate share in determining the colour of the mass; it is usually white or grey. Mica, when black, imparts that hue to the rock, but when, as frequently occurs, it is brown or white, it gives those tints to the substance; while the admixture of hornblende, which is dark green, or black, produces a rock varying between these shades. It is evident, therefore, that a substance, consisting of various minerals, themselves of different hues, and mingled in different proportions, must be correspondingly diversified in tint, and thus we have granites of almost all hues, red, white, black, and grey: the most prevalent being white, which is the tint presented by that of Cornwall; or red, which is the colour chiefly exhibited by the Scottish varieties. A striking example of each kind is exhibited in immediate juxta-position in Waterloo-bridge, where the coping-stone is of the red, while the balustrades are of the white variety. There are other substances which enter into the composition of granite, as chlorite, talc, actinolite, steatite, clevelandite, compact feldspar; but specimens of this nature are comparatively rare.

Granite rises to the highest elevations and forms the

loftiest pinnacles on our globe, and constitutes, at the same time, the skeleton or framework on which most of the other deposits repose. It likewise occurs in the state of beds of irregular shape, among strata of gneiss and other ancient stratified deposits. It is also met with in veins, intruding into rocks of all ages, from those granitic injections which are found to penetrate masses of granite older than themselves, up to similar intrusions into the secondary and tertiary strata. It has been discovered in the Pyrenees, penetrating a rock of the same date as the chalk; syenite, which may be considered a variety of granite, has been found overlying the chalk at Weinböhla, in Saxony, as well as in the county of Antrim, in Ireland; while Mr. Darwin has observed, that the granite of the Cordilleras of South America has been fluid as recently as the tertiary period, and has altered and contorted strata of that date. Granite veins are often found intersected by veins of granite, still newer than themselves, and the rock occasionally occurs as dikes, which are, in fact, similar ramifications on a larger scale, the essential difference being that the dikes continue for a longer distance, while the veins thin out into filaments. Indeed, every mass of granite which forms the central peak of a mountain-chain, is no other than a dike on an enormous scale, which has burst through the superincumbent strata, and borne them upwards in its elevation. While granite is supposed to have generally been erupted in a fluid condition, instances occur in which it has evidently been protruded in a solid state. The proofs of this circumstance are afforded by the absence of any dikes, veins, or filaments ramifying into the surrounding rocks, as well as by the presence of conglomerates and breccias resulting from the grinding and attrition of such rocks by the elevation of the granitic mass. The localities of granite, in England, are Cumberland, Cornwall, and Devon; in Scotland, the Highlands and the Isle of Arran; and in Ireland, the Mourne mountains.

Syenite.—This is granite in which mica is replaced by hornblende, which gives a darker hue to the mass. Its name is derived from the city of Syene, in Upper Egypt, where it largely abounds. The Malvern Hills, in Worcestershire, belong to this group.

Greenstone.—This term is applied to those rocks which

are composed of feldspar and augite, or hornblende. It is closely allied to syenite, differing frequently only in the preponderance of hornblende over feldspar, and the grey or greenish hue thus induced. They frequently pass into each other, and the celebrated head of Memnon, (or rather of Rameses,) in the British Museum,* affords a striking instance of this transition, the body being of greenstone, and the head of syenite, though the whole bust is composed of one continuous mass.

In hypersthene rock, the feldspar is compact or crystalised, and sometimes vitreous, and of a red or white colour. Serpentine is composed of diallage with magnesia; diallage rock, of diallage and feldspar; both are frequently associated with greenstone, and pass into that substance.

Trap Rocks.—These have already been mentioned as deriving their name from a Gothic term for a stair, or terrace, because they occur in tabular masses, rising one above another, like terraces. They comprise the porphyries and basalts in all their varieties of composition and aspect. The term porphyry is derived from a Greek word, signifying purple, from a variety of this stone, used by the ancients for ornamental purposes, which was of a red colour. It is now applied to any rock having a compact base, in which distinct crystals, of feldspar or other minerals, are embedded, and is usually indicated by the name of its base, as feldspar-porphyry, which is by far the most prevalent, claystone-porphyry, pitchstone-porphyry, &c.

Basalt.—Basalt is a term now restricted to masses of hornblende or augite, which contain titaniferous iron, and in which crystals of feldspar are visible. It has a greenish or brownish black colour, is difficult to break, possesses a considerable degree of hardness, but yields to the knife. It occurs both in horizontal tabular masses, and in dikes; and exhibits, in both conditions, the varieties of columnar, globular, vesicular, and amygdaloidal structure. In overlying masses, the columns are usually vertical, in dikes they are frequently horizontal. The celebrated experiment of Mr. Gregory Watt proves that the columnar structure of basalt arises from the pressure of numerous spheroids on

* See the Vignette on the title-page.

each other, in the act of cooling. This gentleman fused seven hundred weight of Dudley basalt, called Rowley ragstone, maintaining the fire for six hours, and allowing it to cool so slowly, that eight days elapsed before it was removed from the furnace. The mass was wedge-shaped, four feet and a half long, two feet and a half wide, eighteen inches thick at one end, and four at the other, an inequality of form admirably adapted for exhibiting the different rates of cooling, and the various kinds of texture thus induced. Where the mass was thinnest, and the cooling most rapid, the texture was vitreous or glassy; where it was thickest, and the cooling slowest, it was stony, while the intermediate parts exhibited a transition state. Numerous spheroids had been formed; where two came in contact, they were compressed, and when several met they formed prisms. We may form some idea of the arrangement, if we conceive a number of cannon-balls to be piled on each other, and reduced to a fluid condition; the pressure of these globular bodies on each other would produce a columnar arrangement, similar to that observable in basalt.

Basalt is frequently vesicular, and contains small cavities, caused by the escape of gases while the rock was in a fused condition. These have been subsequently filled with infiltrations of carbonate of lime, agates, zeolite, and other minerals. As these nodules have in general an elongated shape, similar to an almond, such basalts are termed amygdaloidal. Basalt, like porphyry, has been ejected, in many instances, from fissures in the bed of the ocean, and flowed over the strata there deposited. The chief British localities for these rocks are Durham and Dudley, the Highlands of Scotland, and Edinburgh.

VOLCANIC ROCKS.—Volcanic productions are of so compound a nature, and exhibit varieties of combination so numerous and minute, as to require a separate treatise for their description. The reader is, therefore, referred to the works of Humboldt,* Dr. Daubeny, or Mr. Poulett Scrope;† they are usually divided in trachytic and basaltic lavas. The former are of a light earthy colour, and feldspar is usually an essential element in their composition. The

* Humboldt's Cosmos: Bohn's edition, vol. i. p. 225.

† On Volcanoes.

basaltic varieties contain a considerable proportion of iron, the feldspar being replaced by other minerals, as leucite, they have a dark ferruginous aspect. Mr. Scrope adds a third class, which from being neither decidedly trachytic, nor basaltic, from frequently containing both iron and feldspar, and from being of a tint between the two, he denominates grey-stones. The other volcanic productions are obsidian, or volcanic glass, produced by a rapid cooling; pumice, which is volcanic froth, produced by the access of vapour to the mass when in a fluid condition; and aqueous lava or volcanic mud, caused by the admixture of torrents of rain, or of melted snows, which accompany these eruptions, and which, as they consolidate, form rocks of earthy aspect, called tuff or tufa. These substances frequently pass into each other, both pumice and tufa constantly exhibiting transitions into obsidian. As a general idea of the products of active volcanoes, it may be conceived that all lava is essentially composed of the same elementary fluid substances, and that its subsequent character and appearance are occasioned by the different agencies to which it is subjected. If cooled rapidly it becomes a glass; if slowly, a rock, more or less crystalline, in proportion as its rate of refrigeration is more or less quickened; while the presence of gas and its extrication in cooling, leaves it a light and cellular mass.*

Cause of Volcanoes.—The primary cause of these phenomena is among those problems, the solution of which is reserved for a more advanced state of knowledge. The great quantity of gaseous vapour evolved during eruptions as well as the general proximity of volcanoes to the sea, have led to the supposition that water is the active agent in producing these phenomena, and the two hypotheses proposed to account for their origin, have reference to aqueous action, as having a considerable share in their production. The first ascribes volcanic eruptions and earthquakes to the effects produced on a heated nucleus, mechanically disturbed by the access of water; the other explains the phenomena by supposing the decomposition of water to be effected by means of alkaline metals, existing in the interior in an uncombined

* See an interesting chapter on this subject in Humboldt's Views of Nature Bohn's edition, p. 353.

state. The latter hypothesis, proposed by Sir Humphry Davy, soon after his discovery of the metallic bases of the earths, was subsequently abandoned by him, but has since been revived by Dr. Daubeny.

Similarity of the Ancient and Modern Igneous Rocks.—In taking a general review of the plutonic and the volcanic rocks, it is impossible not to perceive such points of similarity as serve to demonstrate their common origin, and prove them all to be vast portions of melted matter which have been poured out at various times, and under different circumstances, from the interior of the earth. We have alluded to the similarity existing between the products of modern volcanoes and the ancient plutonic rocks, as affording numerous and valid proofs of the igneous nature of both, the student may select the following, as the most convincing of these.

1. They both bear, in many instances, a close resemblance in mineral composition; many of the ancient basalts, as already stated, being scarcely distinguishable from the productions of existing volcanoes.

2. They alike contain mineral substances and crystals in such abundance, as to constitute the chief source whence these objects are derived.

3. They graduate into rocks of like nature and origin with themselves; thus granite passes through syenite and greenstone into basalt, and this last to pitchstone, in a manner analogous to the transition of modern trachyte and basalt into obsidian.

4. They intrude into other rocks, and calcine and alter them at the point of contact, converting coal into coke and anthracite; shale, into mica-schist, or flinty slate; and beds of sandstone into quartz-rock, in so striking a manner that it is possible to trace the effects from the very point of meeting, and to note the passage from the altered to the unaltered rock. The same result, under varied conditions, is also recognised in modern volcanic productions.

To enumerate the whole of the facts which might be adduced to prove the identity of the plutonic and volcanic rocks, would rather burden than assist the memory; and the few proofs above-mentioned, with others which will suggest themselves, will amply suffice.

General Characters of the Igneous Products.—In drawing our description of igneous rocks to a close, we would suggest that the student should commit to memory the following *resumé*:—

1. The granites and their associate rocks, have been formed under conditions of subterranean character, and have melted, and solidified under the pressure of the earth's crust.

2. The trap-rocks, the porphyries, clinkstones, and basalts, are to be regarded as submarine, and as having been melted, and become solid beneath the depth and pressure of the sea.

3. The volcanic rocks are sub-aerial, and have melted, and solidified near the surface, with access of the atmosphere.

Finally, these productions are so similar, that it is by no means unreasonable to suppose that plutonic, trappean, and volcanic rocks, may all be simultaneously forming at the present moment, and that the same volcano which ejects lava and scoriæ from its summit, may, in its internal abysses, at enormous depths and under vast pressure, be elaborating granite; while, from a neighbouring vent, beneath the adjacent seas, it is spreading its waves and terraces of trap over the floor of the ocean.

Metamorphic Rocks.—From the examination of the plutonic and the volcanic rocks, we pass to the consideration of these deposits, which, according to the views now generally entertained, were originally deposited as sediments from water, but have been subsequently altered by subterranean heat.

Gneiss.—Gneiss may be termed stratified, or slaty granite. Composed of the same elements, mica, (or hornblende,) quartz, and feldspar, it differs from that rock, which presents no appearance of stratification, in this distinctive character, that some of its component minerals, usually the mica and hornblende, are arranged in layers, which give a slaty aspect to the mass. The stratification is irregular and contorted, and the dimensions of the strata are variable. When the gneiss is associated with granite, it approaches to the character of that substance; and when the two come in contact, it is scarcely possible to distinguish between them. It is connected with the other primary strata, in the following modes:—By the disappearance of feldspar, it passes into

mica-schist; by the prevalence of quartz, into quartz-rock; and of hornblende, into hornblende-schist. As regards geological position, it reposes on granite, and is succeeded by the other primary strata, frequently alternating in large masses with one or other of these. It occurs in the Western Islands, and North-west Highlands of Scotland.

MICA-SCHIST.—Mica-schist may be regarded as gneiss deprived of its feldspar, being a crystalline compound of mica and quartz united in different proportions. It has a laminar structure, which is more or less perfect, according to the proportion and mode in which the mica enters into its composition. Its colour is determined by the quantity of the same mineral which it contains, and as that substance varies in tint from white, to dark brown, or black, the quartz being usually white or colourless, the prevailing hue of the rock is, therefore, grey. Like the rest of the primary deposits, it graduates into other members of the same series, descending by the admixture of feldspar into gneiss, and ascending by the preponderance of quartz, into quartz-rock. In geological position it follows the gneiss, and is succeeded by various schistose or slaty rocks of crystalline texture, frequently passing into some of these. Its chief localities are the north-west of Ireland, and the Scottish Highlands, especially the picturesque district termed the Trossachs.

The subordinate rocks occurring among the primary strata, may be studied, in some work exclusively devoted to the subject; as Dr. M'Culloch's Western Isles of Scotland, and his Classification of Rocks. They are chiefly of schistose or slaty texture, and are formed by the substitution of one mineral for another, which constitutes the characteristic ingredient of the rock.

Thus, chlorite-schist is composed of the mineral substance termed chlorite and quartz, differing from mica-schist, by its dingy, green aspect, and soapy feel. It graduates by the addition of feldspar into a variety of gneiss, by that of mica into mica-schist, and occasionally assimilates with argillaceous slate.

Talcose slate is composed of talc and quartz. It differs from mica-schist, and chlorite-schist, chiefly in the presence of talc, and in its colours, which are leaden, dingy white, or

green. It occurs with the rocks described above, and passes, by various gradations, into all.

Hornblende-schist is considered to include all hornblende rocks, together with greenstone and greenstone-slate, whether these rocks possess a schistose structure or not.

Quartz-rock is a substance which offers so many variations of mineral character and aspect, that no single description can well define it, and the reader is referred to Dr. M'Culloch's Classification for complete details.

Crystalline, or primary limestone, also presents considerable diversity of texture, ranging from the pure or saccharine variety, so termed from its resemblance to loaf-sugar, to a coarse, impure, and cherty limestone.*

The student should procure a collection of well-defined specimens of these various primary and volcanic rocks. They may be obtained of the parties already mentioned.

Fossiliferous Rocks.—These are divided into well-defined groups, as shown in our table of Classification. They should be studied under the different heads of mineral composition, order of succession, and embedded fossils; for though none of these characteristics is, in all cases, to be relied on by itself, yet when viewed in combination, they will afford complete evidence of the relative date and character of the different stages into which they are subdivided. Of the proofs thus furnished, that derived from organic remains is the most decisive; rocks, which are extremely dissimilar to each other in mineralogical and lithological characters, having been identified by this evidence alone. Professor Agassiz has discovered fossils of the chalk in deposits of totally different mineral texture and aspect; while Sir R. Murchison has identified the mountain limestone in Russia, by the characteristic shells of that formation in rocks of the colour and appearance of white chalk.

Characteristic Fossils.—These may be defined to be such organic remains as, being discovered in any given deposit, are also found in other localities where deposits of the same age occur.

Mineral Veins.—These exist throughout the primary, lower secondary, and in some cases in the tertiary deposits;

* For important information on the Metamorphic rocks the reader is referred to Sir Charles Lyell's Elements of Geology.

but they are far more frequent in the first two classes. They exhibit various peculiarities, many of which the present state of our knowledge does not enable us to explain. Near the surface they are usually poor in the metal but become richer at certain depths, and poor again in lower situations. They also change their metal at different distances from the surface; the same vein, in Cornwall, having been known to contain zinc above, and copper below; while there are mines in the south of France which contain iron above, next silver, and, lastly, copper. They are divided into two kinds; 1st, those which are contemporaneous with the rock itself, and are supposed to have been formed by the separation of the metallic particles from the surrounding mass into one point, and are therefore termed Veins of Segregation; 2nd, the metalliferous lodes, are considered to have been fissures, caused during the elevation of the rocks, which have been subsequently filled by metallic substances. The phenomena of mineral veins constitute problems of considerable difficulty, the full solution of which must be left to a more advanced state of science. For the present it may satisfy the student to be acquainted with those well-ascertained facts which have been established; and the farther consideration of the question may be reserved for future inquiries. The first is their evident connexion with igneous rocks and axes of disturbance, the richest mineral districts are those situated in the proximity of such regions. While Becquerel and Mitscherlich, have succeeded in producing crystals by electricity, Mr. Crosse, of Somersetshire, has obtained calcareous spar from water which had percolated through a limestone rock. The mode by which these remarkable results were effected is highly interesting; the electric apparatus being extremely small, and kept in operation for a long period; the mode in which it is supposed the like results are effected in nature. It is, therefore, assumed that the difference in substances found in veins, and their comparative richness and poorness, have been the consequence of different electric states in the rocks in which they are deposited. Much light has thus been thrown on the nature of these phenomena; and more information is anticipated from observations of like character.

The Gases.—We have alluded to the part which gases take in the formation of the crust of the earth, and to the preponderance of oxygen in rocks. Hydrogen contributes in like manner; it is emitted from volcanoes, and exists in coal. Nitrogen forms four-fifths of the atmosphere, and enters into the composition of animal structure. Carbon forms the principal part of coal; it exists in the state of carbonic acid, in the atmosphere; and forms an important part in all carbonates. It is an essential element in vegetable structure, and is produced wherever vegetable or animal matters are undergoing decomposition. Chlorine occurs chiefly in the sea, in rock-salt, and brine springs. Fluorine exists in some rocks, in minute proportion. Phosphorus is extensively diffused, but its proportions are extremely minute. It is abundant in osseous and other organic remains. Sulphur is found chiefly in the sulphurets and sulphates.

Almost the whole of the simple substances have entered into their present combinations as binary compounds. The following constitute nearly all the binary compounds of the accessible parts of the globe:—1, silica; 2, alumina; 3, lime; 4, magnesia; 5, potassa; 6, soda; 7, oxide of iron; 8, oxide of manganese; 9, water; 10, carbonic acid.

It is calculated that oxygen constitutes fifty per cent. of the ponderable matter of the globe, and that the crust of the earth contains forty-five per cent. of silica, and ten or twelve of alumina. Potassa contributes only seven per cent. of the unstratified rocks, but forms a considerable ingredient in many of the stratified forms: soda nearly six per cent. of some basalts, and other less extensive unstratified deposits, and enters largely into the composition of the ocean. Lime and magnesia are disseminated almost universally, in the form of silicates and carbonates. Iron as an oxide, sulphuret, or carburet, constitutes at least three per cent. of all known rocks; and manganese forms about one per cent. It has often been cited as a fact, which the present state of our chemical knowledge does not enable us to explain, that silica predominates in the unstratified, and carbonate of lime in the stratified deposits.

The mass of rocks is composed of not more than some eight or nine simple minerals. These are 1, quartz; 2, feldspar; 3, mica; 4, hornblende 5, carbonate of lime; 6, talc,

comprising chlorite and steatite; 7, augite; 8, serpentine; 9, iron. Other minerals, which either form rocks of small extent, or enter so largely into their composition as to modify their character, are the following:—Sulphate of lime, diallage, chloride of sodium, coal, bitumen, garnet, schorl, staurotide, epidote, olivine, and pyrites. A few of these minerals exist in masses so large as to be denominated rocks; as quartz, carbonate of lime, sulphate of lime, salt, coal, and pyrites; but in general some two, three, or four are united to constitute a rock, as mica, quartz, and feldspar, to produce granite.

The following general remarks descriptive of some of the peculiarities of rocks, both singly and in groups, may be advantageously borne in recollection:—

Extent of the Older Formations.—The oldest deposits are the most extensive, both as regards area and thickness. In the older and more crystalline rocks we find convincing evidence of the action of fire: as we proceed upwards, the traces of this agency become more indistinct, until, in the newer deposits, with the exception of local sites of extinct volcanic action, we lose all vestiges of its influence.

Derived Character of the Sedimentary Formations.—The sedimentary deposits are produced by the degradation of rocks older than themselves: the sandstones of the coal are extremely micaceous, owing to the mica contained in the primary strata from which they were formed; the new red sandstone was produced from the detritus of rocks of like metamorphic character, and owes its colour to the iron, mica, or hornblende which the older deposits contained. The disintegration of rocks of the primary class is supposed to have yielded many of the argillaceous deposits and beds of clay appertaining to later formations, whilst the chalk, in like manner, has furnished materials for the formation of the tertiary strata.

Similarity of Contiguous Deposits.—It has been remarked, that a character of transition prevails among many contiguous rocks, that the lower members of one formation resemble the upper deposits of the series below. Thus the inferior beds of the lower greensand frequently offer a striking resemblance to the superior strata of the wealden; while the lower members of the oolite, and the

upper deposits of the lias, are, in many cases, scarcely to be distinguished from each other. The same observation applies to the lower beds of the lias and the upper beds of the new red marls.

It is also worthy of remark, that the lower members of any given geological formation, whilst they resemble in lithological character the strata above them, present palæontological characters with the fauna of the rocks on which they repose. Thus, among the fossils of the magnesian limestone the fish bear, in the heterocercal character of the tail, a nearer resemblance to the fossil remains of the carboniferous group beneath, than to those of the new red sandstone above; while those of the upper beds of the lower division of the Silurian system present a closer relation to the types of existence found in the rocks beneath, than in those which occur above them.

Absence of Strata.—The succession of the beds, though never inverted, is occasionally imperfect, and certain members of the series are not unfrequently deficient. This may have been produced by one of two causes; either by the strata having been removed, subsequently to their deposition, or by their never having been deposited in these spots. The former agency admits of demonstration; the latter may require explanation. The disturbances which the crust of the earth has undergone have been so varied, and extensive, that it is supposed that no portion now occupies its pristine position; and in many districts it is concluded that strata have undergone oscillation, similar to that of a board balanced on a fulcrum. In the instance, therefore, of a missing deposit, we have only to suppose a movement of this kind, and to imagine that a portion of a given district has undergone submergence, while an adjacent part has been elevated; we shall immediately perceive that the former has never received those marine deposits which have been accumulated on the latter. By this supposition we are enabled to account for the greatest conceivable difference in the mineralogical and zoological characters of strata which lie contiguous to each other.

Drift is usually classified into two kinds: that which has originated from local sources, and contains pebbles, boulders, &c., derived from the formation in which it occurs; and that

which has been transported from ancient deposits, and is formed chiefly of fragments of older rocks. The most important accumulations of drift in this country are divided into three groups: the first, the Silurian, which overlies the district of that name, and is of local origin, consisting of fragments of the rocks of that formation; the second extends southward from Lancashire, over Cheshire, Staffordshire, Worcestershire, Gloucestershire, and other midland counties, and is composed of fragments of crystalline and trappean rocks, which constitute the mountains of Westmoreland, Cumberland, and part of Scotland; while the third comprises the various deposits which strew our north-eastern coasts and the adjacent districts with fragments of rocks analogous to those now existing in Scandinavia, and furnished either from that region, or from land which once occupied the present bed of the German ocean.

Arenaceous Deposits.—Sandstone is an aggregation of minute particles of quartz; it is usually cemented by a substance of like nature with itself, or the cement may be of the nature of lime, clay, or iron. When sandstone is of extremely coarse grain, it is termed grit.

Argillaceous Deposits.—The substances comprehended in the term clay scarcely admit of a general description; but most of them agree in possessing an earthy texture, and emitting an argillaceous odour when breathed on. They consist of silica, with a variable proportion of alumina, and a small quantity of lime or magnesia. The term is also extended to all kinds of indurated mud, derived from the decomposition and abrasion of various rocks.

Position of Argillaceous Deposits.—It has frequently been mentioned that the lower beds of many formations are argillaceous. This is peculiarly the case in the oolitic series; and is probably owing to the fact, that the alluvial cliffs, or shores, then in existence, being the first which yielded to the action of the waves, provided materials for the earliest strata of the new era; while rocks of firmer texture yielded more slowly to the abrading force, and furnished, at a later period, the material for those arenaceous and calcareous deposits which occupy higher positions.

Calcareous Rocks.—This term comprehends all the series of rocks of which lime forms a prevailing element, including

all the limestones. It is easy to ascertain whether a rock be calcareous or not, by applying dilute nitric or sulphuric acid: if it effervesces, it is calcareous; but if not, it is siliceous. A mixture of sand and clay is usually termed loam, and the combination of calcareous matter and clay is called marl; but both these expressions are employed in a vague sense, and applied to substances of very dissimilar kinds.

Structure of Slaty Rocks.—There are three distinct forms of structure frequently present in rocks of this nature: stratification, joints, and slaty cleavage; the last two having no connexion with true stratification. Joints are natural fissures of various sizes, from mere cracks to open chinks, which often traverse rocks in straight and well-defined lines; while slaty cleavage consists of lines or partings, which form the point at which the stone may be readily divided. Joints, are distinguishable from slaty cleavage, by the fact, that the rock intervening between two joints has no tendency to cleave in a direction parallel to the planes of the joints; whereas, a rock is capable of indefinite subdivision in the direction of its slaty cleavage. As the origin of joints and slaty cleavage constitute problems of considerable difficulty, on which geologists are by no means agreed, it may be sufficient to state, that as these characters are only observable in rocks of crystalline texture, and are most strongly defined in such as are ascertained to have been acted on by heat, we are justified in inferring, that heat has been the chief cause of these results, under whatever conditions it may have operated; and, as a general view, it may be considered that slate rocks having been originally deposited in horizontal planes, the heat has been such as to obliterate these planes, and substitute minute vertical divisions in their stead.

Breccia.—This name is commonly applied to those substances which consist of sharp, angular, unworn pebbles cemented into a mass.

Conglomerate.—This term is usually bestowed on concretions of a similar kind, but in which the imbedded fragments are rounded and waterworn.

Group.—This name is generally applied to a series of rocks of the same mineral composition and geological

character, while the union of several groups is called a period.

Delta.—This name, which was originally bestowed on the deposits formed by the Nile at its mouth, which present the triangular form of this letter of the Greek alphabet, is now applied to all accumulations deposited at the mouths of rivers, whether of this precise shape or not.

Degrading and Elevating Causes.—There are two opposite forces continually in operation on the crust of the globe—the one destructive, and the other conservative; the one consisting in the liability of rocks to be disintegrated and carried away; and the other, in the capability of the materials which they have furnished to be again elaborated into new strata.

Degrading Causes. — These are chiefly atmospheric, fluviatile, or oceanic. The agency of the atmosphere is twofold—chemical and mechanical: the chemical action consists in the absorption of oxygen and carbonic acid from the atmosphere, and the dissolution of the rocks by such absorption. By these means they are speedily weathered, and, to a certain extent, worn away. The mechanical effects consist in the fissuring and cleaving of rocks by frost, and in its abrading and carrying off the solid earth by the action of rills, brooks, and streams, which, when swollen to floods, or collected as rivers, exercise a powerful and destructive force.

Elevating Causes.—As the degrading powers are occasioned by water, so the elevating causes are chiefly owing to fire. They may be regarded as the rapid action of volcanoes and earthquakes, and the slower agency of gradual dynamic forces. The operation of volcanoes is too familiar to require any lengthened explanation. Geologically speaking, the action of a volcano is to raise earthy substances from a low to a higher level. It often effects the most sudden and important changes, and produces a hill on land, or an island in the sea, in a single night. It frequently upheaves the solid strata over a vast area; the coast of Chili, along a line of a hundred miles, and extending from the shore to the Andes, was raised many feet by the earthquakes of 1822. Similar elevations are traced as having occurred in various localities, during the early ages of the earth.

The existence of a dynamic power, which slowly elevates the land above the water, has been proved by the gradual rising of the shores of the Gulf of Bothnia, the northern coast of Sweden, of Denmark, and other parts of Scandinavia, as ascertained by Sir C. Lyell; and that of the south of Italy, by Professor Niccolini, of Naples.

Again, sands are deposited on sea-shores, and are borne inland, where they form extensive accumulations, and overwhelm considerable tracts of land. If these sands are saturated with water containing lime, they become converted into sandstone.

Among other instances in the British Isles, the ancient town of Bannow, in Ireland, called the Irish Herculaneum, has thus been buried in sand. The *Armoricain*, of Brest, states, "that recent gales of wind have displaced a mountain of sand, on the coast of Crozon, near Brest, and exposed to view the remains of a village, and a church surrounded by a churchyard. The oldest inhabitant of the country," adds the journalist, "does not recollect having ever heard of the existence of this maritime Pompeii."

In addition to these mechanical causes, there are vital agencies, which are mainly instrumental in the production of new deposits. The coral polype is incessantly at work beneath the waves, constructing reefs, and building them up to the surface, where they constitute new islands, the junction of which forms fresh continents for the habitation of future races of plants and animals.

Idea of a Geological Formation.—It is, perhaps, scarcely possible to convey to the beginner a more complete idea of a geological formation, than to conceive an existing ocean—the Pacific, for instance—by the elevation of its bed, changed to dry land, since we should thus witness all the varied phenomena observable in the formations of the earth, and in the mineralised beds of its primeval seas. At those points where its largest rivers discharge their waters into the ocean, we should find deposits of silt and mud analogous to the finely laminated clays or marls of our ancient strata. Its calcareous springs would, in numerous instances, cement many of the deposits strewed over its floor to the consistency of stone, and would convert its fragmentary corals and broken shells to beds of limestone. At other

points, we should meet with coral reefs and isles, corresponding with the analogous phenomena of the medial and lower formations of the secondary strata. Beds of gregarious mollusca would offer a resemblance to similar accumulations in the ancient deposits; while the various tribes of zoophytes, crustacea, and fish, would occupy their respective localities, the sponges and corals inhabiting beds and reefs, the shells frequenting the sands of the shore, and the crustacea and the fishes strewn over the floor of the ocean; while the picture would be completed by the exhibition of volcanic agency, exerted both above and below the surface of the waters. Indeed, with the exclusion of the remains and the works of man, we should find a southern ocean of the present day, if changed to dry land, to present a perfect panorama of the most extensive and important formations of the ancient earth, and of the varied phenomena of primeval nature.

The Stratified Rocks.—A stratified rock may be defined to be one whose upper and lower surfaces are parallel

Fig. 58.

to each other; in other words, which exhibits that division into layers and partings, which is recognised in every aqueous deposit, every quarry of limestone, and every pit of chalk, as in the accompanying illustration (fig. 58).

Horizontal Position.—Stratified rocks were originally deposited in a horizontal, or a nearly horizontal position, as here depicted (fig. 59), agreeably to the law by which fluid substances find their level; the fact is demonstrated by the circumstance, that fossils are always deposited conformably to the planes of stratification. This circumstance is beautifully exhibited in the cliffs of Alum and Whitecliff Bays, in the Isle of Wight, where rows of flints and silicified sponges, originally deposited in a horizontal position, are now lifted quite upright, with the beds of chalk which contain them.

Fig. 59.

Disturbance of the Strata.—Subsequently to their deposition, the strata have, in many instances, undergone disturbance, and have been raised at various angles with the horizon.

Vertical Strata.—Occasionally they are lifted almost to a vertical position, as in the following illustration, exhibiting the Silurian strata on which Powis Castle is built.* The chalk and tertiary beds at Alum and Whitecliff Bay, in the Isle of Wight, are likewise nearly vertical.

Fig. 60.

Inverted Position.—In some cases, by the intrusion of igneous rocks, they are actually inverted, and turned back, as instanced in the Malvern hills (fig. 61).

* Sir R. Murchison's Silurian System.

Disjointed Strata.—Fig. 62 presents a similar instance of change in the direction of the strata, produced by a like

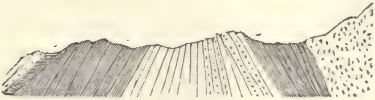


Fig. 61.

cause, and displayed in the same region. Beds which at *b* strike in a southerly direction, on reaching the Malvern syenite at *a*, are thrown into vertical and disjointed masses at *b*.*

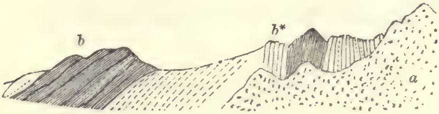


Fig. 62.

Curved Strata.—In other instances they are curved, as is the case with the gneiss, at Oreby, Isle of Lewis, a delineation of which forms the frontispiece to Dr. M'Culloch's Western Isles (fig. 63).

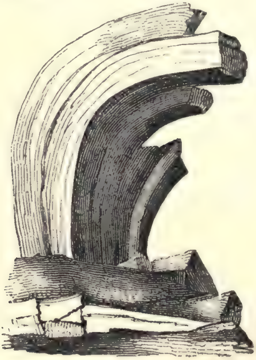


Fig. 63.

ARCHED STRATA.—They sometimes form an arch, as in the Malvern hills (fig. 64).

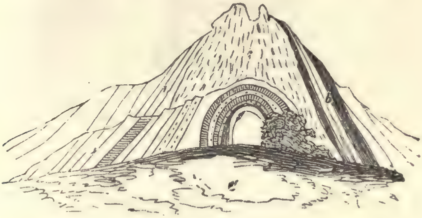


FIG. 64.

CONTORTED STRATA.—Occasionally they are contorted, as on the banks of the Wye (fig. 65), and near May Hill.

FIG. 65.

EXPERIMENTS OF SIR JAMES HALL.—Such contortions were shown by Sir James Hall, by a simple experiment, to have arisen from lateral pressure, attended with some degree of resistance, both above and beneath. He took various pieces of cloth—some linen, some woollen—and placing them horizontally on a table, *c*, covered them by a weight, *a*, acting horizontally on the pieces of cloth.

FIG. 66.

He then applied pressure at the sides, *b b*, and found that, while the superincumbent weight, *a*, was raised to a certain extent, the cloths were folded and contorted, in a manner perfectly analogous to the foldings and contortions of rocks observed in nature, and portrayed in fig. 65.

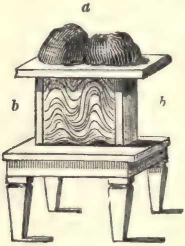


FIG. 67.

UNSTRATIFIED ROCKS.—The unstratified rock differs from

FIG. 68.

the stratified, in presenting none of those parallel surfaces, or divisions into layers, which are remarked in all sedimentary deposits; it usually occurs as a shapeless mass of mineral matter, as in the accompanying figure (fig. 68).

VEINS OF GRANITE AND OTHER IGNEOUS ROCKS.—We have stated that rocks of this kind occur in veins, which, in the instance of granite, are frequently traversed by veins still newer than themselves (fig. 69).

FIG. 69.

These veins have often penetrated through the overlying deposits, and flowed over the rocks which they have displaced, as shown in fig. 70.

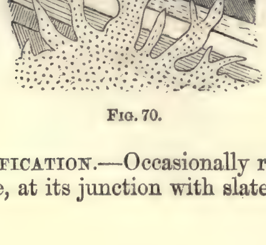


FIG. 70.

FALSE STRATIFICATION.—Occasionally rocks of this kind, especially granite, at its junction with slate and other rocks,

present markings of cleavage, which have some resemblance to stratification, and might be mistaken for such. The student will, however, easily distinguish between the two, not only by the mineral composition of the rocks, but by observing that the lines resembling stratification run into one another in various directions, or are only continued for short distances, as in fig. 71.

Fig. 71.

Columnar Arrangement.—Several of the unstratified rocks, more especially basalt, together with porphyry and greenstone, occasionally assume a columnar form. These columns occur of three, four, five, six, or eight sides, but those with four and six form the prevailing structure. They are either continuous from top to bottom, as in fig. 72,

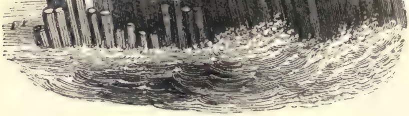


Fig. 72.

or they are jointed, and consist of a number of short prisms, piled on each other, as in fig. 73.

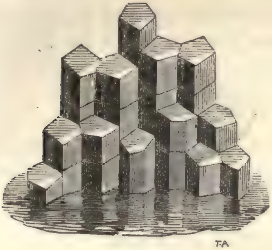


FIG. 73.

VERTICAL COLUMNS.—When basaltic columns occur in tabular masses, as at the Giant's Causeway, or Staffa, they are commonly vertical, as in fig. 74.

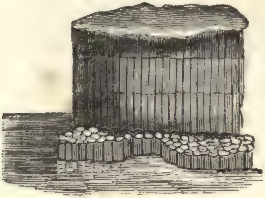


FIG. 74.

HORIZONTAL ARRANGEMENT.—When they occur in dikes, and have been erupted through overlying masses, they are usually smaller, and take a horizontal position, owing, in all probability, to the force with which they have been urged upwards, and the resistance which they have met with from the deposits which they have penetrated, as in this fig. 75.

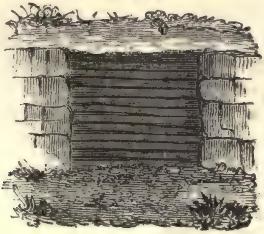


FIG. 75.

Occasionally the columnar and massive structure of basalt are exhibited in conjunction, as in fig. 76.

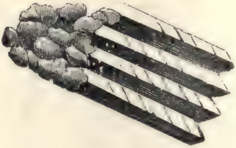


FIG. 76.

ARRANGEMENT OF DEPOSITS.—We have described the unstratified rocks, especially granite, as constituting the foundation and the framework of the whole superstructure of our globe. The accompanying figure exhibits the varied situations of the granite, as forming the basement-rock on which all the others repose, and the nucleus of the mountain, which, having been forced through the superincumbent rocks, has borne them upwards in its ascent; the strata in the vicinity of the mountain, *a*, being raised at an acute angle at *b*, and sinking to nearly a level position in the plains at *c*.

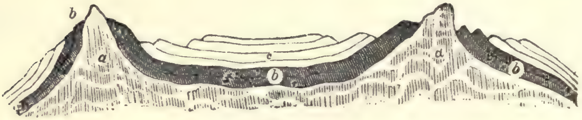


FIG. 77.

The form and succession of the rocks above described prevail, with some local exceptions and modifications, over the whole earth; so that its entire surface may, be considered to form a series of basins, of which the largest, deepest, and thickest lie at the bottom, and are filled up by others, which become smaller, shallower, and thinner as they approach the top, the deposits being uplifted and raised towards the edges of these basins, and becoming level, or nearly so, towards the centre.

Dip.—The inclination of strata from a horizontal position is called their dip, the amount of the dip being the quantity of the angle which the line of inclination makes with that of the horizon, as in the accompanying figure, 78. If the angle made by the meeting of the lines of the strata, *b b*, and the horizontal line, *a*, be equal to 45 degrees towards the east, the strata are said to dip 45 degrees in that direction.

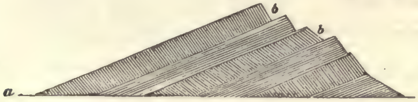


Fig. 78.

Strike.—Again, the various terms of the dip, the strike, &c., of strata, will be farther understood by the following illustration. The dip, as before observed, is the line which the strata makes with the horizon: the strike is a line at right angles to the dip. In other terms, if the student only place a book on the table, with the edges of the leaves downwards, and the back of the book upwards, as in the accompanying figure, and if he move one side of the cover a short distance, the cover so moved, *b*, will represent the line of dip, while the back of the volume, *a*, *a*, will exemplify the line of strike. If the cover of the book be extended only in a slight degree, the dip will be proportionately steep; if the cover be opened farther, so that the book lies nearly flat on the table, the dip will be proportionately less.

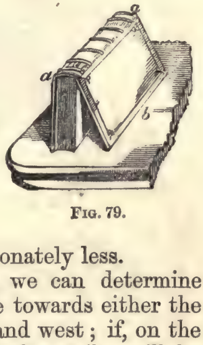


Fig. 79.

Having ascertained the line of dip, we can determine the direction of the strike; if the dip be towards either the north or south, the strike will be east and west; if, on the other hand, the dip be east and west, the strike will be north and south. But the converse of this proposition by no means holds good; for though the line of dip gives the line of strike, the line of strike does not give the line of dip, since there are two lines of dip common to every line of strike, and strata having a line of strike running from

north to south, may dip either to the east or west. In other terms, as we have moved one side of the cover of our book to the right, we can move the other to the left, *b*, while the back of the volume, *a*, *a*, still retains the same position.

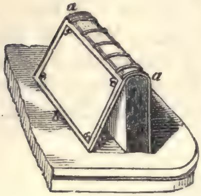


Fig. 80.

Anticlinal Line.—The anticlinal line is that elevated central point from which the strata diverge in opposite directions. To represent it we have only to extend both sides of our volume, as in fig. 81.

Synclinal Line.—The synclinal line is the reverse of the preceding, being the point at which the strata converge towards each other. To depict it we have merely to turn our book over, and open it only half way, exactly at the middle, and the line between the two pages will present the synclinal line, or that point towards which the strata incline in the same direction. (Fig. 82.)

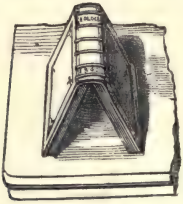


Fig. 81.

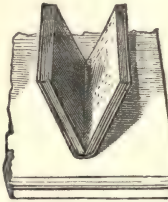


Fig. 82.

The *quâ-quâ-versal* dip, is a term employed to express the appearances presented when the strata having been elevated into a boss, or dome-shaped protuberance, the summit of the dome has subsequently been carried away, and the ground-plan exhibits the edges of the strata, forming a succession of circles or ellipses round a common centre. These circles are the line of strike, and the dip, being always at right angles, is inclined, in the course of the circuit, to every point of the compass, constituting what is termed a *quâ-quâ-versal* dip; that is, turning each way.

Conformable Position.—Strata are said to be conform-

able when their general planes are parallel, whatever may be their dip, as in the following figure, where both the upper, horizontal strata, *a*, and the lower, inclined series, *b*, are conformable to each other.

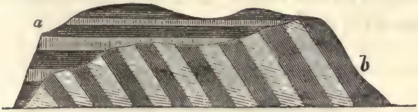


FIG. 83.

UNCONFORMABLE POSITION.—When a series of upper strata rest on a lower formation, without any conformity to the position of the latter, they bespeak a more modern series, showing that the newest of the underlying group must have been deposited before the oldest of the latter. They are therefore said to occupy an unconformable position, as in the same figure 83, where the upper, horizontal beds, *a*, are unconformable to the lower, inclined deposits, *b*.

Occasionally the upper series is also raised, proving that the lower strata have been twice lifted; first, when they were themselves borne upwards; and, secondly, when the upper beds underwent a like elevation.

Various writers have cautioned the observer against certain deceptive appearances of the strata in particular lines of coast, where beds, apparently horizontal, dip, in reality, at a very considerable angle. The following figure exhibits a headland seen from the south, in which the strata appear to the eye perfectly level.

FIG. 84.

But if the headland trends off at the point *p*, (fig. 85) to the northward, affording a view of the cliffs westward, such view will prove that the appearance from the south is deceptive, for the lines on the western side show a considerable angle to the north, and by gradual increase of that angle become vertical at *a*.

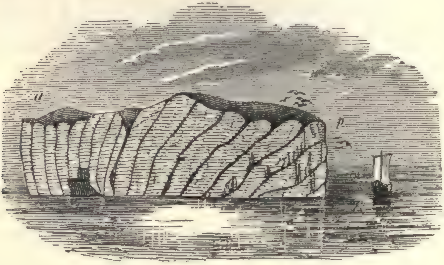


FIG. 85.

ORDER AND SUCCESSION OF ROCKS.—We have stated that the fossiliferous rocks follow an invariable order of succession. That this arrangement, although never reversed, is occasionally imperfect; so that, though we never meet with *b* going before *a*, or *c* preceding *b*, yet we occasionally miss not only a single letter, but a succession of letters, and find, in certain localities, that entire groups of strata are wanting, which occur in other places of like geological character. This effect, we observed, may have resulted either from the missing beds never having been deposited in this spot, or from their having been denuded, and carried away by the abrading power of water, before the newer strata were deposited.

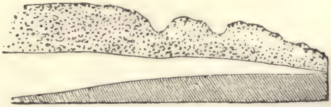


FIG. 86.

Similar causes may have occasioned either the partial depo-

sition or partial denudation of a single bed, and produced the thinning out of a particular stratum, as exhibited in the diagram annexed. (Fig. 86.)

Age of Mountain-chains.—The conformable or unconformable position of the strata affords a safe and satisfactory guide to many investigations of interest and importance; from data thus furnished we learn that the mountain-chains were not all of contemporaneous origin, but have been raised at different epochs. Thus, if on the sides of one mountain (fig. 87) we find a series of strata, *a*, raised and covered unconformably by another group, *b*, it is obvious that the central chain must have been thrown up after the series *a* had been deposited, but before the formation of the beds *b*.

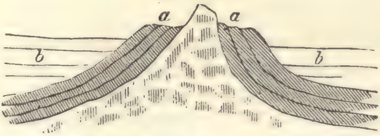


Fig. 87.

But if on the sides of another mountain (fig. 88) we find both the series *a* and *b* tilted and covered unconformably by another series, *c*, we have proofs that this mountain-chain is of more modern date than that on the sides of which the same strata, *b*, are undisturbed.

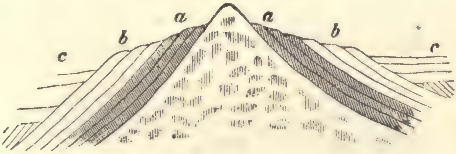


Fig. 88.

Search for Coal.—The dip of strata is frequently connected with questions of practical as well as of theoretical interest. We will suppose a case—one of very frequent occurrence—where a landowner, who is aware that coal exists on an adjacent estate, is desirous to ascertain if it is also to be found on his own, and if the attempt to discover

it might be instituted with any probability of success. It has been observed with reference to such a question, that if the dip of the strata in the vicinity be towards the estate where the trial is to be made, it is probable that the coal may be found under it; but if the dip is in a contrary direction, the search ought not to be undertaken. The accompanying figure will explain the reason.

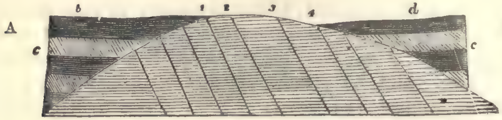


FIG. 89.

The beds 1, 2, 3, and 4, are a series of coal-strata dipping towards *d;* the unconformable strata, *c c*, are beds of sandstone lying over the coal. Supposing the coal-vein 4 rises to the surface at that point on the estate of A, adjoining the estate of B, which lies towards *d*, it is then apparent that A would find only a point of the vein on his estate, and that it would be useless to search in the direction of *b* for coal, since the dip of 4 is sufficient to prove that none exists there. But on the estate of B, though no coal came to the surface, still the dip of that which exists on the estate of A would render it highly probable that coal would be found; the possibility of the coal lying too deep for working, &c., being considerations which would depend on the angle of dip, and other circumstances of local character.

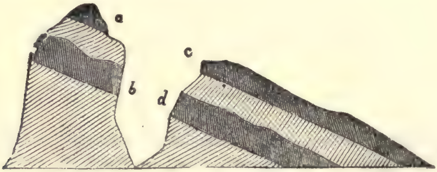


FIG. 90.

OUTLIERS.—Strata are said to form outliers, when they constitute an isolated portion detached from the principal

mass of the same bed of which they once formed a part. Thus, in the accompanying figure 90, the beds *a* and *b* form outliers of the main strata, *c* and *d*; the missing portion having been removed by denudation, and their identity being proved by the accordance of mineral character, position, and imbedded fossils.

Escarpment.—Strata are said to form an escarpment when they terminate abruptly, as at *a*, *b*, in the above figure 90. A mural escarpment is one of a steeper and more perpendicular character.

Origin of Valleys.—When the opinions of Werner more generally prevailed, and water was regarded as the universal agent in producing geological phenomena, many effects were attributed to aqueous agency which are now ascertained to have been occasioned by other causes. It was then usual to refer all valleys to aqueous action, and to consider them as having been produced by the rivers and streams which flow through them. It soon, however, became evident that this cause alone was insufficient, and that in many instances they had been produced by other agencies; these conclusions being founded chiefly on the fact, that many streams, instead of running through soft strata, avoid these, and find their way through rocks of harder texture. It thus became obvious, that the cause is to be sought rather in the rocks themselves, than in the waters which flow over them. Valleys are now divided into four classes, instead of being limited to that of aqueous origin.

Valleys of Dislocation.—These are caused by fissures of various dimensions, some of colossal size, which have been

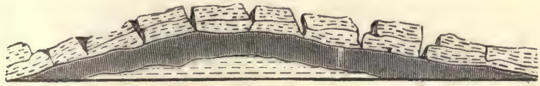


Fig. 91

formed during the upheaval and separation of the strata in the region of which they form a part. They usually present steep escarpments, the strata on each side frequently bearing evidence of former continuity. The mode by which they have been produced will be perceived by the accompanying figure 91.

VALLEYS OF UNDULATION.—These are produced by two neighbouring elevations, which, by lifting the strata on each side without occasioning fracture or dislocation, have left a valley between, towards the middle of which their planes are inclined, and of which they form the sides. Their structure will be understood by a reference to the following illustration (fig. 92).

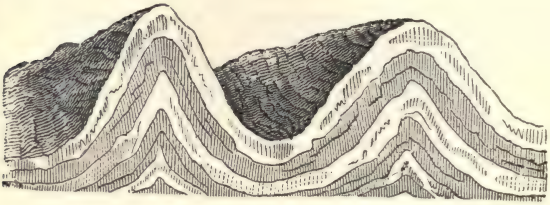


FIG. 92.

VALLEYS OF DENUDATION.—These and the succeeding class have been formed by the action of water on soft and porous strata, in the same manner as the ravines caused by storms, floods, and torrents. Valleys of this kind are of constant occurrence. It is to such erosions that the changes

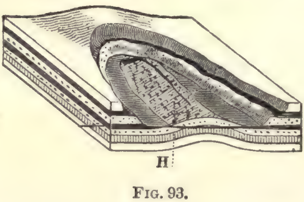


FIG. 93.

are to be ascribed so constantly taking place in the beds of rivers. The term is usually limited to those valleys where the strata are not far removed from a horizontal position, and where their former continuity cannot be doubted (fig. 93).

VALLEYS OF ELEVATION.—These may be described as owing their origin to the circumstance, that certain beds having been originally raised in the form of a wave, have subsequently been exposed to the denuding action of water,

and that a peculiar stratum harder than the rest, having resisted this abrading force, has formed the kind of valley depicted in the accompanying figure (94), presenting a central axis whence the strata dip in opposite directions.

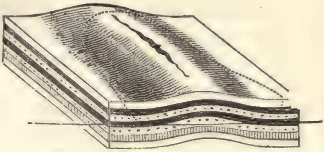


Fig. 94.

Origin of Caverns.—These have been ascribed too

Fig. 95.

generally to the agency of water. It is now ascertained that these chasms are owing to the same causes which have produced fissures and valleys, and that they have been occasioned by the fractures and dislocations consequent on the upheaval of the strata. At the same time it is equally clear,

that the operation of water has, in many cases, tended largely to modify the nature of these caverns, by eroding the sides and the bed, and altering their form and configuration. The fracture and dislocation of rocks at the surface have often produced the phenomenon of a natural bridge, as exemplified in the accompanying figure (95), which depicts that of Iconozo, in South America, which is produced by the fissuring of the strata, and the fall of two masses of rock, one above the other, extending across the chasm.

Faults.—The fissures and dislocations which interrupt the continuity of a bed are termed faults. The accompanying figure (96) represents an example of this kind, where strata which once were continuous, either by the subsidence of the strata on one side of the fault, or their elevation on the other, have been dislocated and displaced

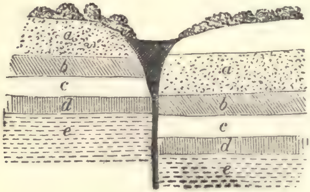


Fig. 96.

These interruptions are a source of considerable difficulty in coal-mines, where they often suddenly interrupt the miner in his course, and deprive him of the treasure which he has found. They, however, offer corresponding advantages, since they counteract the tendency of the coal-seams to plunge to depths at which it would be impossible to reach them; and when filled with solid materials, they form embankments which keep out the water, that would otherwise flood the mine, and prevent the possibility of working it; they also act as barriers, and stop the progress of flames.

Deceptive Appearance of Faults.—These disturbances, however, frequently prove a source of loss and disappointment to inexperienced persons, who, observing different appearances of coal at the surface, conclude that they represent so many separate seams; whereas, in reality, a single

seam has only been dislocated and moved to different levels, by means of faults, as figs. 97 and 98.

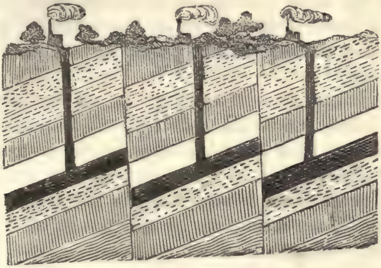


FIG. 97.

EQUIVALENT.—Where one bed supplies the place of another, which in that situation is wanting, such stratum is called the equivalent of the missing deposit. When a bed suddenly terminates, and its place is supplied by one of different character, the latter is also called the equivalent of the former.

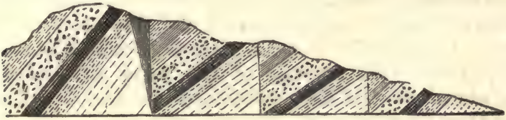


FIG. 98.

There are some other varieties of texture, as well as different phenomena in rocks, which may be here mentioned.

PISOLITES.—The pisolitic structure in certain stones is occasioned by isolated globules formed of concentric layers. They are produced by water holding foreign substances in solution, and possessing such a power of motion as to enable them continually to transport with them the grains of sand occurring in their course. Each of these grains becomes covered on all sides with successive pellicles of the substance deposited by the fluid, and it thus increases, assuming the spheroidal form, until becoming too heavy for transport it falls to the bottom of the liquid, where the whole are agglu-

tinated together. Occasionally each pisolite encloses in its centre a grain of foreign substance; but this is by no means a necessary condition, and the original nucleus may be a particle of the same substance in which it is enclosed. The oolitic structure, particularly of the coarser kind, strongly resembles the pisolitic, and is considered to be owing to a similar cause.

Rolled Pebbles.—Running waters have the effect of rounding those materials which they wash out of the beds by the attrition and abrasion occasioned by such transport. A familiar illustration is furnished by the beach formed at the base of chalk cliffs, where none of the flints present sharp edges, being all worn smooth by the action of the waves.

Nodules.—Substances which have consolidated in the midst of semi-fluid matters often owe to the resistance thus opposed to them a reniform or kidney-like shape, such objects being smooth externally, when the substance of which they are composed is little susceptible of crystallisation, and furnished with crystals when it is. The former case is instanced by nodules of silex; the latter, by various substances of more crystalline character, among others, the masses of iron pyrites discovered in the same deposits.

Geodes.—Occasionally nodules of silex, and other substances, are hollow in the interior, and they are then termed *geodes*. The nodules of quartz, which present this form, are usually lined with crystals of the same substance; they occur abundantly in the counties of Somerset and Devon, where they bear the name of potato-stones.

Incrustations as distinguished from Petrifactions.—Waters which flow over limestone rocks have the power of dissolving a portion of the lime, and on reaching the colder temperature of the atmosphere, they deposit it again in a solid state; a familiar example of this operation being furnished by the *fur*, as it is termed, of the tea-kettle, which is formed by the water which has boiled, having deposited, on cooling, a portion of the lime which it previously held in solution.* Certain springs in this country, as well as on the Continent, are famed for this property; among the former, those of Knaresborough and Matlock are

* The carbonic acid of the water held the lime in solution; boiling expels the gas, and causes the lime to fall down as a sediment.

the most celebrated. Objects exposed to the action of these waters become incrusted with a coating of carbonate of lime, and in this state they are improperly termed petrifactions, since they are merely incrusted with the stony matter, not permeated by it. For example, if we place any organic substance, as a piece of wood or bone, in an incrusting spring, we find that the object is merely coated with the stony matter, but internally is wood or bone still; whereas in real fossils, not only the mere external covering, but the whole of the interior structure, is converted into stone.

Authors.—The objects comprised in the term Physical Geology are so numerous and diversified, that we must again refer to the authors already named for more ample information. They may be severally consulted with advantage, for the following purposes: For the elements and combinations of rocks, read Dr. M'Culloch's Classification of Rocks, his System of Geology, and his Western Isles of Scotland; as also the Introduction of Mr. Bakewell, and the Guide and other works of Professor Phillips: for the action of water in currents, streams, rivers, lakes, and seas, and the dynamics of the subject, the writings of Sir H. T. Delabeche, Dr. Hutton, and Professor Playfair, may be studied; while the works of Sir C. Lyell will be found replete with instruction in every department of geology.

EXERCISES

ON PHYSICAL GEOLOGY.

1. Commit to memory the fourfold division of rocks enumerated at the commencement of the chapter.

2. Impress on the recollection, the most important characters and distinctions of the primary rocks, for the reason that they are less clearly defined than those of the sedimentary deposits.

3. Commit to memory the names of the successive formations, together with the distinctive features of each, under the heads of mineralogical character, order of succession, and

contained fossils. Ascertain the extent and depth of each formation, the counties in which it occurs, its relation, value, and importance, in an agricultural, economical, or commercial point of view, and commit to your note-book any general information relating thereto.

4. Be careful to unite practice with theory, in the inquiries above suggested, and trace every group on a geological map.

5. Ascertain the continual progress of geological inquiry, on the debateable points of drift, the glacial theory, the transport by icebergs, &c.

6. Describe the component elements of granite, gneiss, and mica-schist, with their arrangement in each.

7. What are syenite, greenstone, hornblende?

8. Name the characteristic features of the trap-rocks.

9. Describe porphyry and basalt.

10. Mention the principal volcanic products, with their chemical composition.

11. State the general characters of the igneous rocks.

12. Explain the nature of elevating and degrading causes.

13. Describe the composition of calcareous and arenaceous deposits, and the most ready mode of distinguishing them.

14. State the cause of drift, and the chief instances of its occurrence.

15. Describe the structure and origin of slaty rocks.

16. What is meant by the term alluvium, and what are its distinctions?

17. Explain the various terms, group, formation, series, system, breccia, conglomerate, dip, strike, conformable and unconformable position, outlier, denudation, anticlinal and synclinal axis, escarpment, valleys of dislocation, undulation, denudation, and elevation, &c.

18. Explain the difference in appearance and character of a stratified and unstratified rock.

19. State, in detail, the phenomenon of nature best adapted to afford an idea of a geological formation.

20. Copy, or otherwise impress on the recollection, the diagrams comprised in the preceding chapter.

21. Consult the works of Murchison, Conybeare, Phillips, Buckland, Mantell, Bakewell, &c., which treat of physical geology, and copy on tracing paper their outlines and delineations.

CHAPTER VII.

FOSSIL BOTANY.

Authors:—Lindley, Hutton, Artis, Witham, Buckland, Sternberg, Presl, Göppert, Cotta, Schlotheim, Brongniart, Mantell's Pictorial Atlas.

Museums:—British Museum, Geological Society, Economic Geology, Newcastle, Dudley, Manchester, Leeds, Scarborough, Whitby, Glasgow Collections, &c.

The science of Fossil Botany is of modern origin. M. Adolphe Brongniart observes, that scarcely any mention of fossil vegetables occurs in ancient writers, and that the few observations of Theophrastus and Pliny are too vague and obscure to be of any value. The silence of Greek and Roman authors ought not to surprise us; coal, which constitutes the great depository of fossil plants, being wanting, or undiscovered, in the regions chiefly inhabited by these nations; while in Germany, France, and England, where coal is chiefly found, the Romans were more intent on establishing their domination, than in studying the natural resources of those regions; the extensive woods which then covered so large a portion of the surface, affording a sufficient supply of fuel, without compelling a recourse to those mineral stores afforded by the entombed forests of the primeval earth.

Coal, however, is mentioned by Theophrastus, Siculus Flaccus, and St. Augustine. It is supposed to have been known also to the Roman occupants of our island, cinders and pieces of coal having been found in Roman roads and walls, and Roman coins discovered in beds of cinders. It is farther conjectured to have been known to the British aborigines, hammer-heads, wedges, and axes of flint, having been found in beds of coal; while the name of the substance is not Saxon, but British. A people who are known to have wrought veins of tin, lead, and copper, could not have remained

ignorant of a substance which often lies so much nearer the surface than these minerals, and fragments of coal are constantly washed out of its native beds, and borne into the plains by rivulets and streams. There is historical evidence of its having been known and employed in the ninth century, during the occupation of the Saxons; it is also mentioned shortly after the Norman Conquest. Æneas Sylvius, who visited this island about the middle of the fifteenth century, and afterwards became Pope Pius II., in a well-known passage, mentions, with evident surprise, that he saw in Scotland poor people in rags begging at the churches, and receiving for alms pieces of stone, with which they went away contented. "This species of stone," he observes, "whether with sulphur, or whatever inflammable substance it may be impregnated, they burn in place of wood, of which their country is destitute."

The study of fossil botany commenced with the general working of coal, and though the same erroneous ideas prevailed with reference to vegetable, as to animal fossils; yet the clearness and distinctness of their forms showed that they were actual plants; while the evidence of drift which they exhibited, occasioned them to be ascribed to the action of the deluge. It was not, however, till about the commencement of the last century that the researches and the publications of La Hire, and in particular of Scheuchzer, on the continent, and of Lloyd and Lister, in our own country, drew the attention of the scientific world to this remarkable department of natural science. At a later date, the writings of Leibnitz, Wolkmann, Mylius, Maraldi, and Jussieu, not only proved the general distribution of these fossils over a great part of Europe, but the Memoir of Jussieu, published in the Transactions of the Academy of Sciences, in 1708, is eulogised by M. Brongniart, as a work truly remarkable for its epoch; since it possesses the distinguished merit of establishing the dissimilarity which exists between the plants of the coal, and the existing vegetation of those portions of Europe in which they are now found, and their analogy with species peculiar to warmer regions at the present day.

As earlier observers had been sceptical as to the vegetable origin of these fossils, later inquirers went to the opposite

extreme, and, not content with acknowledging them to be the remains of the vegetable kingdom, recognised in their imperfect impressions the characters of existing plants, and pointed out ears of corn and maize, flowers of the tulip and the aster, and the fruit of the pine-apple!

The true characters and relations of fossil plants were studied and determined by the labours of Schlotheim, and Faujas de St. Fond, on the continent; Parkinson and Artis, in this country; and Steinhauer, in America, up to the distinguished continental botanists, Sternberg, Presl, Cotta, Nœggerath, Agardh, Nillson, Nau, Martius, and Brongniart; and their worthy fellow-labourers in this country, Witham, Bowman, Lindley, and Hutton.

The most useful works on the subject are the *Prodrome* and the *Histoire des Végétaux Fossiles*, by Adolphe Brongniart; the *Versuch einer Geognostisch-Botanischen Darstellung der Flora der Vorwelt*, by Count Gaspar Sternberg, continued, after the blindness and decease of this venerable and ardent cultivator of science, by Presl. As the foreign publications here enumerated are large and expensive, and chiefly relate to forms of plants derived from foreign localities, and not occurring so frequently in this country, the reader is recommended to commence with the excellent English work, entitled the Fossil Flora, by Lindley and Hutton.

Classification of Vegetables.—The student of fossil botany will find it expedient to follow the method prescribed for other branches of natural science, and commence the study of the present vegetation of the earth as the means of deciphering that of the past. The following sketch will afford an outline of the classification of the vegetable kingdom. For more ample details we refer to the admirable Introductions by Sir William Hooker, Sir J. E. Smith, Dr. Lindley, &c.

The classification of Jussieu, usually termed the Natural System, is that now generally adopted. According to this method, plants are divided into two great divisions. The first consists of those which are composed entirely of cellular tissue, are destitute of vessels, and whose embryo or germ has no cotyledons, or seed-leaves, whence they are termed *acotyledonous*; they are also named *cryptogamic*, from κρυπτος

and γαμος, concealed marriage, because no parts of fructification have yet been discovered The other division comprises such as are more complicated in structure, being furnished with cellular tissue and tubular vessels, and the embryo having one or more *cotyledons*, whence they are called vascular or *cotyledonous*, and are subdivided into the *dicotyledonous*, or *exogenous*, and the *monocotyledonous*, or *endogenous* classes.

Exogenous or Dicotyledonous Structure.—A transverse section of a branch of the oak (fig. 99) exhibits a

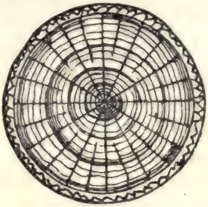


Fig. 99. Transverse section of dicotyledonous wood.

central, cellular substance or pith; an external cellular and fibrous ring, or bark; an intermediate woody mass, and certain fine lines, radiating like the spokes of a wheel, from the pith to the bark through the wood, and called medullary rays.

Fig. 100 Germ of a dicotyledonous plant.

This is the structure of an *exogenous* plant, so called from εξω, without, and γενναω, to increase, because its mode of growth is by fresh layers from without, from the circumference to the centre; it is also termed *dicotyledonous*, because its germ has two *cotyledons*, or seed-leaves (fig. 100).

Plants of this kind compose the greater part of our European trees, and their leaves have nerves much branched and running into each other.

ENDOGENOUS OR MONOCOTYLEDONOUS STRUCTURE.—In the cane, neither bark, nor pith, nor wood, nor medullary rays, are distinguishable; but a transverse section of a stem exhibits a large number of holes, irregularly arranged, and caused by the section of vessel-like tissue, and the mass of woody or cellular substance in which they lie embedded (fig. 101).

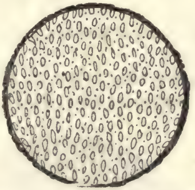


FIG. 101. Transverse section of monocotyledonous wood

A longitudinal section exhibits similar differences, as in figs. 102, 103.

Plants of this latter class are called *endogenous*, from *ενδον*, within, and *γενναω*, to increase, because their growth takes place from within, from the centre to the circumference;

FIG. 102.
Longitudinal section of dicotyledonous wood.

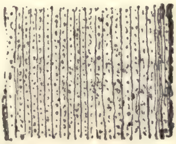


FIG. 103.
Longitudinal section of monocotyledonous wood.

they are also styled *monocotyledonous*, because the germ has but one *cotyledon*, or seed-leaf (fig. 104).

Trees of this class prevail most abundantly in tropical climates, and the nerves of their leaves run parallel to each other. So constant are the characters of the two kinds of venation in the leaves, that an experienced botanist, on inspecting the fragment of a leaf, is able to distinguish

the *dicotyledonous* nature of a plant from the fibrous interlacing of its vessels, as seen in the apple (fig. 105),

FIG. 104. Germ of a monocotyledonous plant.

or the *monocotyledonous* character in the smooth and parallel veins of the *gloriosa superba* (fig. 106).

FIG. 105.

CONIFEROUS PLANTS.—In some families of the *dicotyledonous* class, the cells, or tubes, are marked with spots or glands (fig. 107).

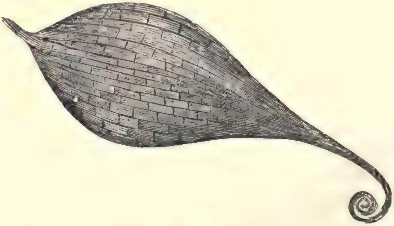


FIG. 106.

This is peculiarly the case with the *coniferæ*, which form a large and very important tribe among living plants. They are characterised not only by peculiarities in their fructification, having, together with the *cycadeæ*, their seeds originally

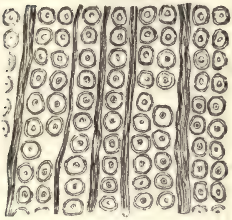


FIG. 107.

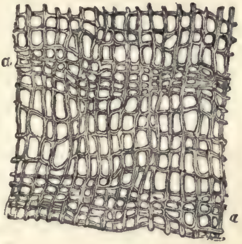


FIG. 108.

naked, and not enclosed in an ovary, for which reason they have been arranged as a distinct order; but they are still farther distinguished by the peculiarity of their woody structure, whereby the smallest fragment can readily be identified. A transverse section of any coniferous wood, in addition to the radiating and concentric lines, exhibits a system of reticulations by which *coniferæ* are distinguishable from other plants. The cross lines *a, a,* indicate the annual circles of growth (fig. 108).

Among other characteristics of trees of this order, they all secrete resin, have branched trunks, and linear, entire, rigid leaves, and they occur both in the hottest and coldest regions. It should be observed that the minute structure of wood above described can only be studied by the aid o the microscope.

INVESTIGATION OF FOSSIL PLANTS.—The object chiefly desired by the student of fossil botany, is to acquire such a degree of knowledge as will enable him to determine a fossil plant with facility and correctness, and to refer it to the genus and species to which, if already known, it belongs. The remarks of Dr. Lindley and M. Brongniart on these points are so important and instructive, that we have transferred to our pages the substance of their observations.

In recent plants, the botanist has the opportunity of examining the organs both of fructification and vegetation, and, from their structure, is enabled to judge of the class, order, or genus to which the specimen belongs; but in a fossil plant, the only parts capable of being examined are the internal structure of the stem, and its external surface, together with the position, division, outline, and venation of the leaves.

Thus if the subject of inquiry be a fragment of the fossil trunk of some unknown tree, if no trace can be ascertained of its exact anatomical structure, it may be possible to ascertain whether its wood was deposited in concentric zones, or grew after the manner of the cane; in the former case, it would have been dicotyledonous, or exogenous; in the latter, monocotyledonous, or endogenous. If a transverse section should show the remains of sinuous unconnected layers, resembling arcs, or parts of a circle, with their ends outwards, of a solid homogeneous character, and embedded among some softer substance, then it may be considered certain that such a stem belonged to some tree-fern. If the tissue is altogether cellular, and it can be satisfactorily ascertained that no vascular tissue is combined with it, the specimen, in all probability, belonged to that division of the vegetable kingdom, termed *cryptogamia;* care being observed to examine it rigorously, lest it prove a succulent portion of some dicotyledonous tree, in which the vascular system is so scattered among cellular substance as to be scarcely discernible. If the tissue consists of tubes placed parallel with each other, without any trace of rays passing from the centre to the circumference, it is endogenous, even if there be an appearance of concentric circles in the wood; but if any trace whatever can be discovered of tissue crossing the longitudinal tubes at right angles, from the centre to the circumference, such a specimen is exogenous, whether concentric circles can be made out or not; for such an arrangement of tissue would indicate the presence of medullary rays, which are the most certain sign of a dicotyledonous stem. If, in a specimen having these medullary rays, the longitudinal tubes are all of the same size, a circumstance obvious upon the inspection of a transverse section, the plant is either coniferous or cycadeous; but if among the smaller tubes, which

in fact, are woody fibres, some larger ones are interspersed *in a definite manner*, in that case it belongs to some other tribe of dicotyledons. It is indispensable that the arrangement of the larger tubes should be *definite*, for appearances of the same kind exist in most coniferous wood; but in the latter they are scattered in an *indefinite* manner, among the smaller tubes, and are not vessels, but cylindrical cavities for the collection of the resinous secretions peculiar to the fir-tribe. If the walls of the longitudinal tubes of any fossil specimen are found to exhibit appearances of little warts, or excrescences growing from their sides, such a specimen is to be referred to some coniferous or cycadeous plant, as no other tribes present such a structure. If a trace of pith can be discovered, that circumstance alone proves the plant to be dicotyledonous, because all other classes are destitute of that central, cellular column; it being remembered, at the same time, that as the roots of dicotyledonous plants are destitute of pith, the absence of pith does not prove the plant not to have been of that order, as the part examined may have been a portion of the root.

If a stem is in such a state that nothing can be determined respecting its anatomy, it will be necessary to judge of it by another set of characters. In the first place, it should be inquired whether it had a distinctly separable bark; in the second, if it had a cortical integument that differed, in its organization, from the wood, without being separable from it; or, thirdly, if it possessed neither the one nor the other. In the first place, it would have been dicotyledonous; in the second, monocotyledonous; in the third, acotyledonous, supposing it had been a trunk which many successive years had contributed to form. The distinction, as applied to the two latter classes, is not, however, so positive as could be wished, because tree-ferns have a cortical integument; but they are easily known by the long ragged scars left by their leaves; and no other cryptogamic plants possess the character of having a spurious bark.

A third, and very important kind of evidence, is to be collected from the scars left upon stems by the fall of the leaves. Although these will neither inform us of the shape nor other characters of the leaves themselves, yet they indi-

cate with precision their position, the form of their base, and sometimes also their probable direction: we can tell whether they were opposite or verticillate, alternate or spirally disposed, deciduous or persistent, imbricated or remote, —all characters of great use as means of discrimination, and as frequently affording important negative evidence on doubtful points.

Care must be taken not to mistake, for different species, those stems which still retain their cortical integument, as distinguished from such as have lost it. In the two cases the appearance of the scars will be different; those of the former being more rounded, broader, and more deeply furrowed than the latter; for the one is a real scar, showing the outline of the base of the leaf, while the latter is solely caused by the passage of vessels out of the stem into the petiole or footstalk.

In leaves we can rarely recognise, in a fossil state, more than their mode of venation, division, arrangement, and outline, to which are sometimes added their texture and surface. All these are of importance, but in unequal degrees. The distribution of the veins, taken together with the mode of division of a leaf, affords evidence of the highest value. If the veins are all parallel, unbranched, or only connected by little transverse bars, and the leaves undivided, the plant was probably monocotyledonous; and if the veins of such a leaf, instead of running side by side, from the base to the apex, diverge from the mid-ribs, and lose themselves in the margin, forming a close series of double curves, the plant was certainly analogous to what are now called *scitamineæ*, or *marantaceæ*, or *musaceæ;* but supposing that the parallel arrangement of simple veins is combined with a pinnated foliage, then the plant would probably have belonged to *cycadeæ*, that curious tribe which stands on the very limits of monocotyledonous and dicotyledonous, and of flowering and flowerless plants.

If the veins are all of equal thickness, and dichotomous, we have an indication of the fern tribe, which is seldom deceptive. Nevertheless, it must be remembered that the flabelliform leaves, both of monocotyledons and dicotyledons, have occasionally this kind of venation. Even if the veins are not dichotomous, if they are all of nearly equal thick-

ness, and very fine, or divided in a very simple manner, it is probable that they indicate the fern tribe, whether simple, as in the fossil genus *tæniopteris*, or reticulated, as in the modern genus *meniscium*. If the veins are of unequal thickness, and so branched as to resemble the meshes of a net, we have a sign of dicotyledonous structure that seldom misleads us. Finally, if no veins are to be found, an opinion must be formed, not from their absence, but from other circumstances. If the leaves are small, their absence may be due to incomplete development, but if they are large and irregularly divided, we may have an indication of some kind of marine plant. When the leaves are small and densely imbricated, they are generally considered to belong either to *lycopodiaceæ* or *coniferæ;* but there is so little to distinguish these families in a fossil state, that there is scarcely any means of demonstrating to which of these such genera as *lycopodites, lycopodendron, juniperites, taxites,* &c., and the like, actually belong.

ARRANGEMENT OF FOSSIL PLANTS.—M. Adolphe Brongniart has divided the vegetation of the ancient earth into four periods. The first commences with the earliest traces of vegetable life, and terminates with the carboniferous epoch; the second concludes with the triasic; the third comprises the oolite and chalk; and the fourth the tertiary period. In his *Prodrome d'une Histoire des Végétaux Fossiles,* the following comparative table of the extinct and living classes of plants is given:—

	First Period.	Second Period.	Third Period.	Fourth Period.	Living.
Agamiæ	4	5	18	13	7000
Cryptogamiæ cellulosæ . .	.	.	...	2	1500
——— vasculosæ . .	222	8	31	6	1700
Phanerogamiæ gymnospermiæ	...	5	35	20	150
Monocotyledoniæ . . .	16	5	3	25	8000
Dicotyledoniæ	...	.	...	100	32000
Indeterminate . . .	22	.	...	...	......

This table has now been published some years, during which several new species have been discovered; but the general proportions remain much the same.

REMARKS OF COUNT STERNBERG.—These four periods Count Sternberg reduces to three, by uniting the second and

third into one, and calls the first that of islands, the second of coasts, and the third of continents.

The flora of the first era, terminating with the coal, was simple, but magnificent, and extremely elegant in its forms, consisting of plants which either have no existing analogues in the present creation, or such as are now limited to the torrid zone. The accompanying illustration depicts the character of these plants (fig. 109). That of the second presents few analogies of genera, and probably none of species, with those of the period preceding; and thus the first flora, which was universally diffused over the whole earth, was strongly distinguished (*scharf abgeschnitten*) from the second. The annexed engraving portrays the flora of the triasic, oolitic, and wealden groups. (Fig. 110.)

Vegetation of the coal.

a Arborescent fern. *b* Pecopteris. *c* Asterophyllites. *d* Neuropteris. *e* Lepidodendron. *f* Calamites. *g* Araucaria. *h* Casuerina.

Fig. 109.

The second passed imperceptibly into the third, which comprises the tertiary formations, and is only distinguished by the change in the relative numbers of acotyledonous and monocotyledonous, as compared with dicotyledonous

plants, as well as by the more European character of its vegetation.

OF DR. LINDLEY.—The observations of Dr. Lindley on the periods of Brongniart, are in substance these :—

In the first, comprising the coal formation, the flora of that era consisted of ferns in vast abundance ; of large coni-

d a b c b b

Vegetation of the oolitic period.

a Arborescent fern, peculiar species. *c* Pandanus.
b Cycas and zamia. *d* Palmi.

FIG. 110.

ferous trees ; of species resembling *lycopodiaceæ*, but of most gigantic dimensions ; of vast quantities of a tribe apparently analogous to *cacteæ*, or *euphorbiaceæ*, but perhaps not identical with them ; of palms and other monocotyledons ; and, finally, of numerous plants, the exact nature of which is extremely doubtful. Of the entire number of species detected in this formation, two-thirds are ferns.

In the trias, the characters of vegetation are altered by the disappearance of the *cacteæ*, or *euphorbiaceæ*, by a diminution of the proportion of ferns, and by the appearance of a few new tribes ; but so little is known of the flora of this period, that it is scarcely worth noticing as a distinct epoch, but might more appropriately be classed with the period succeeding.

In the lias and oolites, an entirely new race of plants covered the earth. The proportional number of ferns is here diminished: the gigantic lycopodium-like, and cactoid plants of the coal measures, the *calamites* and palms, all disappear; but species, undoubtedly belonging to *cycadeæ*, and analogous to plants now natives of the Cape of Good Hope and New Holland, appear to have been common. Coniferous plants were still prevalent, but they were of species which did not exist at an earlier period.

Up to this time, the features of vegetation were extra-European, and chiefly tropical, but immediately succeeding the chalk, a change analogous to that observable in the animal kingdom took place. The eocene group is characterised by a total absence of *cycadeæ:* the number of ferns is strikingly diminished, and *coniferæ* increase in quantity; while mixed with palms and other tropical monocotyledons, there grew elms, willows, poplars, chesnuts, and sycamores, together with numerous other dicotyledonous plants, which increased in number and variety, till the flora of the more recent tertiary beds has little to distinguish it from that of the present day.

Experiment of Dr. Lindley.—The great preponderance of ferns, and the other higher forms of cryptogamic plants, in the flora of the ancient earth, having excited the attention of naturalists, and it being conjectured that the absence of certain genera, and the presence of others, might be accounted for by a difference in the capability of one plant beyond another of resisting the action of water, Dr. Lindley resolved on trying the following experiment. On the 21st of March, 1833, he filled a large iron tank with water, and immersed in it 177 specimens of various plants, belonging to the more remarkable natural orders; taking care to include representatives of those which are either constantly present in the coal-measures, or as universally absent. The vessel was placed in the open air, and left uncovered and untouched, with the exception of filling up the water as it evaporated, till the 22nd April, 1835, when the following results were obtained.

In the first place, it was found that the dicotyledonous plants, in general, had wholly disappeared, whence it was inferred, that they were unable to remain for two years in

water without being totally decomposed; the principal part of those which remained belonged to the *coniferæ* and *cycadeæ*, the families, in fact, which we find best preserved in a fossil state. Secondly, the monocotyledons survived to a considerable extent, whence it was concluded that they are more capable of resisting the action of water, in particular, palms and scitamineous plants, families which are likewise found fossil. Grasses and sedges had perished; whence it was inferred that we have no right to assume that the earth was not originally clothed with these, because we no longer find their remains. Thirdly, fungi and mosses, and all the lowest forms of vegetation had disappeared; even *equisetum* had left no traces behind; ferns appeared to have the power of resisting water if gathered in a green state, not one of them having disappeared during the experiment; but immersion had caused their organs of fructification to rot away; a result which we constantly observe in the fossil specimens.

Hence, it is assumed, as a general result, that the numerical proportion of different families of plants, found in a fossil state, throws but little light upon the ancient climate of the earth; but depends in some measure upon the power which certain families possess, by virtue of their organisation, of resisting the action of the water in which they floated, previously to their being finally embedded in the rocks in which they are found.

In addition to these statements, it may be remarked, that as the circumstances under which the plants of the coal were entombed, were analogous to those which attended the submergence of the flora of the tertiary period, we should expect to find that, if dicotyledonous plants had existed in any considerable numbers during the carboniferous epoch, they would have left their impression on the shales, in the same manner as the tertiary plants have left their imprints on the deposits of that period.

On the other hand, if we consider the *sigillariæ* to belong to the dicotyledonous class, we shall have a much larger numerical proportion of plants of this order than was supposed to have existed at this epoch.

Objections of Count Sternberg.—The whole subject, however, is replete with difficulties, which the present state

of our knowledge by no means enables us to explain. Count Sternber *su* ggests the following contradictions and anomalies as arising out of the experiment just described. He fully admits the antiseptic quality of ferns, which, he remarks, had previously been demonstrated in the shipwreck of the late M. Dumont d'Urville, in which his plants having been submerged, and afterwards recovered, the grasses and ferns were saved, while the dicotyledonous plants were lost. He next observes, that it would seem that the *equisetaceæ* were all destroyed; yet this family is well preserved in the period extending from the carboniferous to the chalk groups; while, on the other hand, the ferns of the tertiary flora must have perished, since we are only acquainted with a few species from the brown coal, which cannot be supposed to represent all the ferns that lived in the tertiary period, seeing that they constitute the majority of the plants from the coal to the chalk, and are also abundant in the present creation. In conclusion, he suggests the probability, that the experiment having been made with pure water, may not have produced the same chemical effects on the plants, as was the case with those of the coal, which were immersed in water so impure and admixed with sediment, as to have deposited the clay-slate in which they are preserved.*

Classification of Plants.—We now proceed to describe the arrangement of the vegetable kingdom in detail, and shall offer a brief description of those fossil plants which are of most frequent occurrence, in treating of the classes to which they belong.

The vegetable kingdom is divided by M. Adolphe Brongniart into six classes.

1. The agamiæ.
2. The cellular cryptogamiæ.
3. The vascular cryptogamiæ.
4. The gymnosperm phanerogamiæ.
5. The monocotyledonous phanerogamiæ.
6. The dicotyledonous phanerogamiæ.

The following are the observations of M. Brongniart, explanatory of the above arrangement:—

"The first class is that of the *agamiæ*, a term which, how-

* See Flora der Vorwelt, p. 83.

ever, we may consider as possibly expressing only our ignorance. This class comprises the different families confounded under the names of *algæ*, *fungi*, and *lichens*. The characters common to all these vegetables are as follows: they are entirely formed of cellular tissue, or rather of interlacing tubular filaments, without vessels properly so called; they never present true leaves, and their organs of reproduction consist only of very fine seedlings, which appear to develope themselves without fecundation, and are immediately inclosed in membranous conceptacles analogous to the filaments of that tissue which composes the whole of the plant. The only fossil plants of this class known are some *confervæ*, with several *algæ*.

"The second class, that of the cellular *cryptogamiæ*, comprises the two families of *hepaticæ*, or liverworts, and *musci*, or mosses; their organs of vegetation, although solely composed of cellular tissue, offer, in most cases, leaves well characterised by their form, their structure, and by the fact that they are similar to those of the most perfect vegetables. Their organs of reproduction present a more complicated structure; there are sexual organs very distinct, which have been perfectly described by Hedwig; the seedlings are contained in conceptacles of very complex organisation. One fossil plant only is known as appertaining to this class.

"The third class, that of the *vascular cryptogamiæ*, includes those vegetables, the more varied tissues of which almost always include perfectly distinct vessels, and very frequently spiral vessels or imperfect spiral vessels, while the leaves are in general very fully developed, and furnished with cortical pores; the stems, which are often large and arborescent, have some analogy with those of *monocotyledons;* and finally, the organs of reproduction always appear to consist of two distinct sexes, which produce seedlings inclosed in conceptacles of a somewhat complicated organisation. To this class belong the *equisetaceæ*, the ferns, the *lycopodiaceæ*, the *marsiliaceæ*, and the *characeæ*.

"In the fourth class, under the name of *phanerogamic gymnosperms*, we unite the two remarkable families of *cycadeæ* and *coniferæ*, which really cannot be confounded by associating them in either of the other classes with vegetables, from which they are so distinct by the structure of their organs of

reproduction, since their seeds, being destitute of capsules, receive directly the action of the fecundating substance; and from which they are also distinguished by the organisation of their stems, which differ in many respects from those of true *dicotyledons*.

"Finally, the fifth and six classes are formed of *phanerogamic monocotyledons* and *dicotyledons*, as they are defined by all botanists, omitting only the two families composing the preceding class.

"If, on the one hand, the above arrangement presents but little uniformity in the relative extent of the six grand primary divisions here described, three of them, the *agamiæ*, the *monocotyledons*, and *dicotyledons*, comprising a considerable number of families, genera, and species, while the remainder, in particular the fourth, include only a very limited number; on the other hand, we preserve a far more essential uniformity in the importance of the characters; the groups which we obtain are, moreover, perfectly natural, and we do not meet with those contradictory disparities which it is impossible to avoid in dividing the vegetable kingdom only into three grand classes."

We subjoin a tabular arrangement of the various families which compose the classes above mentioned.

Class I.—AGAMIÆ.

1st Family.—Confervæ.
2nd Family.—Algæ.

Class II.—CELLULAR CRYPTOGAMIÆ.

3rd Family.—Mosses and Liverworts.

Class III.—VASCULAR CRYPTOGAMIÆ.

4th Family.—Equisetaceæ, the horse-tail tribe.
5th Family.—Ferns.
6th Family.—Marsiliaceæ, the pepperwort tribe.
7th Family.—Characeæ, the chara tribe.
8th Family.—Lycopodiaceæ, the club mosses.

CLASS IV.—PHANEROGAMIC GYMNOSPERMS.

9th Family.—CYCADEÆ.
10th Family.—CONIFERÆ, the fir tribes.

CLASS V.—MONOCOTYLEDONOUS PHANEROGAMIÆ.

11th Family.—NAIADES.
12th Family.—PALMS.
13th Family.—LILIACEÆ, the lily tribe.
14th Family.—CANNEÆ.

CLASS VI.—DICOTYLEDONOUS PHANEROGAMIÆ.

15th Family.—AMENTACEÆ, the birch tribe.
16th Family.—JUGLANDEÆ, the walnut tribe.
17th Family.—ACERINEÆ, the sycamore tribe.
18th Family.—NYMPHEACEÆ, the water-lily tribe.

CLASS I.—AGAMIÆ.

The first class, that of *agamiæ*, so called from *a* privative, and *γαμος*, marriage, because no organs have been discovered which distinguish them as male and female flowers, comprises the first family, that of the *confervæ*, and the second that of the *algæ*, or sea-weeds, some few of each being found in a fossil state. We subjoin from Brongniart a figure of *fucoides targionii* discovered by Dr. Mantell in the glauconite, or fire-stone of the chalk formation.

FIG. 111.

Class II.—CELLULAR CRYPTOGAMIÆ.

The second class, that of the *cellular cryptogamiæ*, includes the third family, that of the liverworts and mosses.

Class III.—VASCULAR CRYPTOGAMIÆ.

The third class, that of the higher order of cryptogamous plants, entitled *vascular cryptogamiæ*, constitutes the bulk of the plants of the coal, and comprises the extensive tribes of *equisetaceæ*, or horse-tail family; the ferns; the *marsiliaceæ*, or pepperwort family; the *characeæ*, or chara family; and the *lycopodiaceæ*, or the club mosses. But, though resembling the recent tribes above mentioned, the fossil plants far surpass them in size. Thus the *equisetum*, or horse-tail, is a small, slender, elegant plant of our ponds and ditches, not more than half an inch in diameter, having an erect, succulent, jointed stem, with verticillate fringes of linear leaves growing round the joints, and bearing spikes of fructification on the summit. Plants of this family are abundant in the coal; but they are, comparatively, of gigantic species, exceeding a foot in circumference.

4th Family.—Equisetaceæ.

We subjoin a figure (112) of the existing *equisetum*, for the purpose of comparing it with that of the fossil *equisetum columnare*, from Brongniart, and of *calamites cannæformis*, from Lindley and Hutton. (Figs. 113, 114.)

Fig. 112.

5th Family.—Ferns.

We next arrive at the ferns, which form so large a proportion of plants of the coal, and which, in their size and proportions, present so striking a contrast to the diminutive genera of this region at the present day. The common brake, or fern, exhibits a type of the family; but the arborescent ferns which now grow only in the vicinity of the equator, present the closest

analogy to the ferns of the carboniferous period, which were lofty trees, far surpassing in height and magnificence even their tropical congeners of the present day. A splendid specimen of *alsophila brunoniana*, placed on the staircase of the British Museum, affords an idea of the arborescent ferns of the tropics, which attain the height of forty or fifty

Fig. 113.
Equisetum columnare. Br. Pl. 120.

Fig. 114.
Calamites cannæformis. Schlot.

feet, their stems being marked with scars from the decay of the leaf-stalks, and their summits crowned with a spreading dome of graceful foliage. The scars resemble those of other monocotyledonous plants, especially the palms, but differ in the circumstance that in the ferns they are commonly longitudinal, while in the palms they are transverse. From their number and variety, they afford some of the most interesting fossil remains which the vegetable kingdom has produced. Their leaves are elegant, and display great variety of form and diversity of venation: from these characters the generic and specific distinctions of the family are obtained. They are often preserved in great perfection, and even the organs of fructification are occasionally observable at the back of the leaf.

The fossil ferns are divided into the following genera, determined by the character of their fronds:—*pachypteris, sphenopteris, cyclopteris, glossopteris, neuropteris, odontopteris, anomopteris, tæniopteris, pecopteris, lonchopteris, clathropteris, schizopteris, otopteris, caulopteris*, and *sigillaria, &c.*; the two latter occurring only as stems; the last being considered by some recent inquirers as a dicotyledonous plant.

We shall now give a brief description of the most common genera, with the figure of a typical species.*

Pachypteris, from *παχυς*, thick, and *πτερις*, a fern.

Fig. 115.

Leaves pinnated, or bipinnated, leaflets entire, coriaceous, ribless, or one-ribbed, contracted at the base, but not adherent to the mid-rib.

Two species only have been discovered; in the oolite formation.

The accompanying is a figure (115) of *P. lanceolata*, from Brongniart, Pl. 45.

Sphenopteris,† from *σφην*, a wedge, and *πτερις*, a fern.

Leaves bitripinnatifid; leaflets contracted at the base, not adherent to the rachis. Lobed; the lower lobes largest, diverging, somewhat palmate; veins bipinnate, radiating, as it were, from the base.

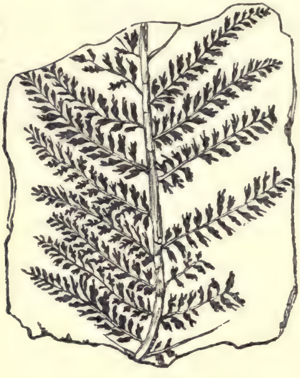


Fig. 116.

We give, as an example, the *S. crenata* (fig. 116), from Lindley and Hutton, Pl. 39. The species amount to about thirty-six.

Cyclopteris,‡ from *κυκλος*, a circle, and *πτερις*, a fern.

Leaves simple, entire, and somewhat orbicular; veins numerous, radiating from the base, dichotomous, equal; mid-rib wanting.

One species in the transition rocks.

Four species in the coal.

One species in the oolites.

* Pictorial Atlas of Organic Remains: H. G. Bohn.—This splendid volume contains seventy-four beautiful illuminated plates, containing nearly nine hundred figures, selected from Parkinson's Organic Remains and Artis' Antediluvian Phytology, with descriptions by Dr. Mantell. As this Atlas will prove eminently useful to the student, we shall make constant reference to the plates in the following pages.—Pict. Atlas, pl. iv., figs. 1—7.

† Pict. Atlas, pl. iv., figs. 3, 4; pl. v., fig. 2.

‡ Pl. v., fig. 5; pl. xxix.

We add a figure of *C. Beanii* (fig. 117), from Lindley and Hutton, Pl. 44.

FIG. 117.

Glossopteris, from γλωσσα, a tongue, and πτερις, a fern.

Leaves simple, entire, somewhat lanceolate, narrowing gradually to the base, with a thick vanishing mid-rib; veins oblique, curved, equal, frequently dichotomous, or sometimes anastomising, and reticulated at the base.

Two species in the coal.

One species in the lias.

One species in the oolite.

The subjoined illustration depicts *G. Phillipsii* (fig. 118), from Lindley and Hutton, Pl. 63.

FIG. 118.

Neuropteris, from νευρον, a nerve, and πτερις, a fern.

Leaves bipinnate, or rarely pinnate; leaflets, usually, somewhat cordate at the base, neither adhering to each other, nor to the rachis by their whole base, only by the middle portion of it; mid-rib vanishing at the apex; veins oblique, curved, very fine, dichotomous. Fructification; sori lanceolate, even, covered with an indusium, arising from the veins of the apex of the leaflets, and often placed in the bifurcations.

Twenty-four species in the coal formation.*

Three species in the new red sandstone.

One species in the anthracite of Savoy.

One species in the muschelkalk.

We subjoin a figure of *N. Loshii* (fig. 119), with a magnified leaflet, from Lindley and Hutton, Pl. 49.

FIG. 119.

FIG. 120.

Odontopteris, from οδους, a tooth, and πτερις, a fern.

Leaves bipinnated; leaflets membranous, very thin, adhering by all their base to the rachis; mid-rib absent or rudimentary; veins equal, simple, or forked, very fine, most of them springing from the rachis.

Five species in the coal formation.

We insert above a figure of *O. minor* (fig. 120), from Brongniart, Pl. 77.

* Pict. Atlas, pl. xxviii.

Anomopteris, from *a* privative, *νομος*, a law, and *πτερις*, a fern.

Leaves pinnated; leaflets linear, entire, somewhat plaited transversely at the veins, having a mid-rib; veins simple, perpendicular, curved. Fructification arising from the veins, uncertain as to form; perhaps dot-like, and inserted in the middle of the veins; or perhaps linear, attached to the whole of a vein, naked as in *meniscia*, or covered by an indusium, opening inwardly.

One species in the new red sandstone.

Tæniopteris, from *ταινια*, a fillet, or wreath, and *πτερις*, a fern.

Leaves simple, entire, with a stiff, thick mid-rib; veins perpendicular, simple, or forked, at the base. Fructification dot-like.

Three species in the lias and oolite formations.

We add a figure of *T. vittata* (fig. 121), together with a magnified leaflet, from Lindley and Hutton, Pl. 62.

FIG. 121.

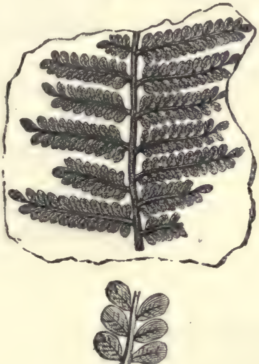


FIG. 122.

Pecopteris,* from a word unknown to the author, and *πτερις*, a fern.

* Pict. Atlas, pl. iv., fig. 7; pl. v., figs. 6, 9; plates xxx., xxxi., xxxii.

Leaf once, twice, or thrice, pinnate; leaflets adhering by their base to the rachis, or occasionally distinct; mid-rib running quite through the leaflet; veins almost perpendicular to the mid-rib, simple, or once or twice dichotomous.

Sixty species in the coal formation.*

Two species in the lias.

Ten species in the oolites.

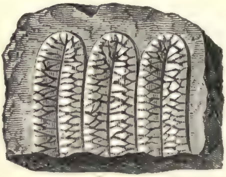
One species in the beds above the chalk.

The accompanying figure is that of *P. adiantoides* (fig. 122), with magnified leaflet; from Lindley and Hutton, Pl. 37.

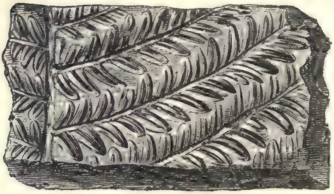
Lonchopteris, from λογχος, a spear, and πτερις, a fern.

Leaf many times pinnatifid; leaflets more or less connate at the base, having a mid-rib; veins reticulated.

Two species in the coal formation.



1.



2.

FIG. 123.†

One species in the green sand formation.

One species in the Wealden. *L. Mantelli* (fig. 123).

Clathropteris, from κλειθρον, a lattice, and πτερις, a fern.

Leaf deeply pinnatifid; leaflets having a very strong complete mid-rib; veins numerous and simple, parallel, almost

* See many plates in the Pict. Atlas.

† Fig. 1, a portion of three leaflets magnified; fig. 2, part of a stem, with leaves.

perpendicular to the mid-rib, united by transverse veins, which form a net-work of square meshes upon the leaf.

One species in the lias.

Schizopteris, from σχιζα, a fissure, or division, and πτερις, a fern.

Leaf linear, plain, without mid-rib, finely striated, almost flabelliform, dividing into several lobes, which are linear and dichotomous, or rather irregularly pinnated and erect, lobes dilated and rounded towards the extremity.

One species in the coal formation.

Otopteris, from ους, an ear, and πτερις, a fern.

Leaf pinnated; leaflets originating obliquely from the side of the leaf-stalk, auricled, attached by about half their base, destitute of all trace of mid-rib. Veins of equal size, very closely arranged, diverging from their point of origin, and dividing dichotomously at an exceedingly acute angle.


FIG. 124

We annex a figure of *O. acuminata* (fig. 124), from Lindley and Hutton, Pl. 132.

Caulopteris, from καυλος, a stem, and πτερις, a fern.

This is a term formed to describe those stems which, from their markings, are considered by Dr. Lindley to be true stems of ferns; those figured or described as being so by Sternberg, Brongniart, and others, under the name of *sigillaria*, *favularia*, &c., not being now regarded as such.

6th Family.—MARSILIACEÆ, OR PEPPERWORT TRIBE.

This family comprises the doubtful genus. *Sphenophyllum*,* rotularia, of Sternberg.—Branched, deeply furrowed; leaves verticillate, wedge-shaped, with dichotomous veins

Eight species in the coal formations.

* Pict. Atlas, pl. v., fig. 7.

7th Family.—CHARACEÆ, OR CHARA FAMILY.

Chara, gyrogonites, of Lamarck.—Fruit oval, or spheroidal; consisting of five valves, twisted spirally, a small opening at each extremity; stems friable, jointed, composed of straight tubes, arranged in a cylinder.

Five species in the tertiary formations.*

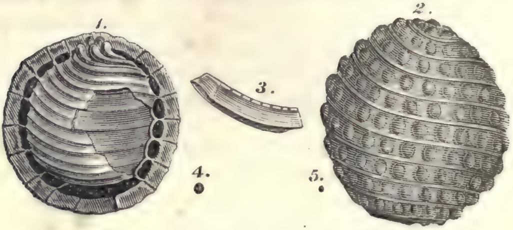


FIG. 125.—FOSSIL SEED-VESSELS OF CHARÆ.
(*Sir C. Lyell.*)

Fig. 1.—*Chara medicaginula;* a section showing the nut within the pericarp.
2.—*Chara tuberculata;* the pericarp.
3.—Portion of a spiral valve, magnified.
4 and 5.—The natural size of figs. 1 and 2.

8th Family.—LYCOPODIACEÆ, OR CLUB-MOSSES.

Lycopodites,† lycopodiolithus, and walchia, of Sternberg.—Branches pinnated; leaves inserted all round the stem in two opposite rows, not leaving clean and well-defined scars.

Ten species in the coal formation.

One species in the sandstone of the lias.

One species in the inferior oolite.

One species in the marl below the chalk.

The accompanying figure (126) delineates *L. Williamsonis*, together with a cone and magnified leaflet, of Lindley and Hutton, Pl. 93.

Selaginites.—Stems dichotomous, not presenting regular elevations at the base of the leaves, even near the lower end of the stems. Leaves often persistent, enlarged at their base.

Two species in the coal formation.

Lepidodendron, from λεπις, a scale, and δενδρον, a tree, sagenaria, of Sternberg.—Stems dichotomous, covered near their extremities by simple linear or lanceolate leaves, in-

* Pict. Atlas, pl. lxii., figs. 23, 24. † Pict. Atlas, pl. vi., figs. 27 to 29.

serted upon rhomboidal areolæ; lower part of the stems leafless; areolæ longer than broad, marked near their upper part by a minute scar, which is broader than long, and has three angles, of which the two latter are acute, the lower obtuse, the latter sometimes wanting.

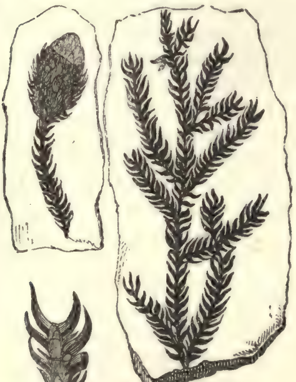
Several species in the coal formation.*

Ulodendron.—Stem covered with rhomboid alareolæ, which are broader than long; scars large, few, placed one above the other, circular, composed of broad cuneate scales, radiating from a common centre, and indicating the former presence of organs, that were, perhaps, analogous to the cones of *coniferæ.*

Two species in the coal measures.

Lepidophyllum.—This term signifies leaves, which it is conjectured may have belonged to *lepidodendron;* they are

Cone.



Magnified leaflet. Fig. 126.

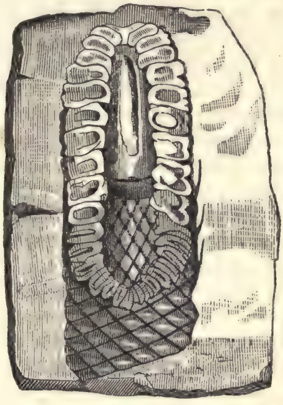


Fig. 127.

sessile, simple, entire, lanceolate, or linear, traversed by a single mid-rib, or by three parallel ribs. No veins.

Lepidostrobus.—This name indicates cones ovate, or cylindrical, composed of imbricated scales, inserted by a narrow base around a woody axis; their points sometimes dilated and reversed in the form of rhomboidal disks. Seed solitary, oblong, and winged, nearly as long as the scales.

* Pict. Atlas, pl. iii., fig. 4; pl. xxvi., page 199.

Five species in the coal formation.

We insert a figure of *L. ornatus* (fig. 127).

These cones are supposed to have belonged to *lepidodendron:* but Mr. Hawkshaw found beneath each of the magnificent, erect fossil trees discovered by him on the Bolton and Manchester Railway, a number of cones lying in such a position as indicated their having fallen from the tree. Corda declares them to be the male flowers of *coniferæ.* The trees were pronounced by the late Mr. Bowman to be *sigillariæ.*

Professor Corda, in a Supplement to his Sketches of the Anatomy of Stems, has some further observations on the *lepidostrobi.* He considers them as divisible into three forms; the first comprising *L. pinaster*, Foss. Flo. fig. 198: and *L. ornatus* var-*didymus*, Foss. Flo. fig. 163. These he regards as fragments of stems, referring *L. pinaster* to Presl's genus of *lycopodites*, *Bergera pinaster*, and *L. ornatus* to *Cycadites ornatus.* The second form includes *L. ornatus*, Foss. Flo. fig. 26, which he considers as a fruit of yet unknown and problematical kind; while the third comprises true *lepidostrobi*, viz. *L. variabilis*, Foss. Flo. fig. 10, *L. comosus*, Foss. Flo. fig. 162, and the specimens figured by Brongniart, vol. ii. fig. 22 and 23. He adds, that these last will require more investigation than the two preceding forms, and that to ascertain their structure and assign their due character and position, it will be advisable, at the same time, to take up the investigation of the fruit of *lycopodiaceæ*, with which they are compared by Brongniart; then to determine their peculiar structure, and to compare it with those groups and families to which they are referred above.

Cardiocarpon, from *καρδιον*, the heart, and *καρπος*, fruit.

These are heart-shaped fruits, five species of which occur in the coal formation.

Stigmaria. Variolaria, Sternb.; mammillaria, Brongn.; ficoidites, Artis.

Stem originally succulent; marked externally by roundish tubercles, surrounded by a groove, and arranged in a direction more or less spiral, having internally a distinct woody axis, which communicates with the tubercles by woody processes. Leaves arising from the tubercles, succulent, entire,

* Pict. Atlas, pl. ix., fig. 1.

and veinless, except in the centre, where there is some trace of a mid-rib.

Five species in the coal formation.*

One species in the oolite formation, viz.:—Mammillaria Desnoyersii, of Brongn. Ann. sc. 4, t. 19, f. 9, 10.

We subjoin a figure (128) of *S. ficoides*, Lindley and Hutton, Pl. 34.

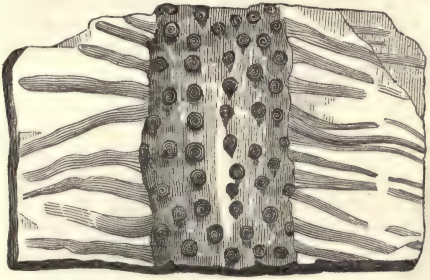


FIG. 128.

CLASS IV.—PHANEROGAMIC GYMNOSPERMS.

Having figured those genera which occur most commonly in the coal measures and other strata, we shall merely give descriptions of most of the remaining plants, and, with one or two exceptions, refer for the plates and other details to the works of Brongniart, Sternberg, Lindley and Hutton, and the Pictorial Atlas.

9th Family.—CYCADEÆ.

LEAVES ONLY KNOWN.

Pterophyllum, from *πτερον*, a wing, and *φυλλον*, a leaf.—Leaves pinnated; leaflets almost equally broad each way, inserted by the whole of their base, truncated at the summit; veins fine, equal, simple, but little marked, all parallel.

Eight species in the lias and oolite.

We subjoin a figure of *P. comptum* (fig. 129), with magnified leaflet, Lindley and Hutton, Pl. 66.

Cycadites.—One species in the grey chalk.

Eight species in the oolite formation.

* Pict. Atlas, pl. xxi. to xxiii.

Nillsonia.—Two species in the lias.

Zamia.—Fifteen species in the oolite and lias.*

One species from a deposit unknown.

STEMS ONLY KNOWN.

Cycadeoidea, Buckland, Mantellia, Ad. Brongn.—The following dicotyledonous plants are of doubtful affinity:—Phyllotheca, annularia, bechera, asterophyllites, &c.

As this last genus is of frequent occurrence in the coal, we subjoin a figure (130) and description of *asterophyllites foliosa,* Lindley and Hutton, Pl. 25.

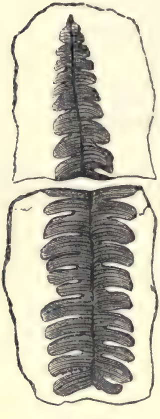


FIG. 129.

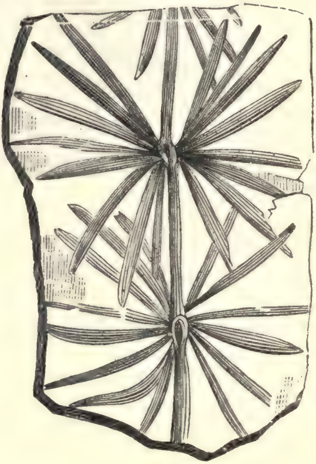


FIG. 130.

Asterophyllites. Bornia, Sternb.; Bruckmannia, Sternb.—Stem scarcely tumid at the articulations, branched; Leaves verticillate, linear, acute, with a single mid-rib, quite distinct at their base.

Twelve species in the coal formation.†

One species in the transition rocks.

This is considered to be an extremely heterogeneous assemblage, comprehending nearly all fossils with narrow,

* Pict. Atlas pl. iii., fig. 5. † Pict. Atlas, pl. v., fig. 10, 11.

veinless, verticillate leaves, which are not united in a cup at their base.

10th Family.—Coniferæ, the Fir Tribe.

WOOD ONLY KNOWN.

Pinites.—Three species in the coal formation.
Peuce.—One species in the coal formation.
One species in the oolite.
Pinus.—Nine species in the tertiary strata
Abies.—One species.
Taxites.—Five species in the tertiary beds.
One species in the oolite formations.
Podocarpus.—One species in the tertiary fresh-water formations of Aix.
Voltzia.—Four species in the new red sandstone.
Thuia.—Three or four species in the new red sandstone.
Thuytes.—Four species in the schistose oolite.

DOUBTFUL.

Brachyphyllum.—One species in the lower oolite formation.

Class V.—MONOCOTYLEDONOUS PHANEROGAMIÆ.

11th Family.—Fluviales.

Zosterites.—Four species in the lower green sand.
One species in the lias.
Two species in the upper fresh-water formation.
Caulinites.—One species in the London clay.

12th Family.—The Palms.

STEMS ONLY KNOWN.

Palmacites.—One species in the lower beds of the London clay.

LEAVES ONLY KNOWN.

Flabellaria.—One species in the coal.
Three species in the tertiary formations.
Phœnicites.—One species in the tertiary formations.
Noeggerathia.—Two species in the coal measures.
Juniperites.—Three species in the tertiary beds.

Cupressites.—One species in the new red sandstone.
Zeugophyllum.—One species in the coal formation.

FRUIT ONLY KNOWN.

Cocos.—Three species in the tertiary formations.

13th Family.—LILIACEÆ, THE LILY TRIBE.

Bucklandia.—One species in the Stonesfield slate.

FIG. 131.—WATERWORN STEM OF THE CLATHRARIA LYELLII.
From the shingle in Brook Bay.
(*One-third linear, nat. size.*)

Clathraria.—One species in the green sand, and one in the chalk.

LEAVES ONLY KNOWN.

Convallarites.—Two species in the variegated sandstone.

FLOWERS ONLY KNOWN.

Antholithes.—One species in the tertiary beds.

14th Family.—CANNEÆ.

Cannophyllites.—One species in a bed of coal.
Monocotyledonous plants of doubtful affinity.

STEMS ONLY KNOWN.

Endogenites.—Several species from the tertiary strata.

Culmites.—Three species from the tertiary beds.
Sternbergia.—Columnaria of Sternberg.*
Three species in the coal formation.

LEAVES ONLY KNOWN.

Poacites.—Several species in the coal formation.
Phyllites. Potamophyllites of Brongniart.—One species in the lower fresh-water formation.

FRUITS ONLY KNOWN.

Trigonocarpum. Ad. Br.—Five species in the coal formation.
Amomocarpum. Ad. Br.—One species in the tertiary formations.
Musocarpum. Ad. Br.—Two species in the coal formation.
Pandanocarpum. Ad. Br.—One species in the tertiary strata.

Class VI.—DICOTYLEDONOUS PHANEROGAMIÆ.

15th Family.—Amentaceæ, the Birch Tribe.

Carpinus, betula, and comptonia.—One species of each in tertiary lignite.

DOUBTFUL AMENTACEÆ.

Salix, populus, castanea, and ulmus.—In upper fresh-water formation.

16th Family.—Juglandeæ, the Walnut-tree Tribe.

Three species in the tertiary strata.
One species in the upper beds of new red sandstone.

17th Family.—Acerineæ, the Sycamore Tribe.

Some dubious leaves found near Frankfort.

18th Family.—Nympheaceæ, the Water-lily Tribe.

Nymphæa.—Upper fresh-water formations.
Flowering plants which cannot, with certainty, be referred to either the monocotyledonous or dicotyledonous class.

* Pict. Atlas, pl. xviii.

Æthophyllum, echinostachys, and palæoxyris.—One species of each in the new red sandstone.

Plants, the affinity of which has hitherto been regarded as uncertain, but which are now referred with great probability to the dicotyledonous division.

Sigillaria. Rhytidolepis, alveolaria, favularia, catenaria, &c., of Sternberg.—Stem conical, deeply furrowed, not jointed; scars placed between the furrows in rows, not arranged in a distinctly spiral manner, smooth, much narrower than the intervals which separate them.

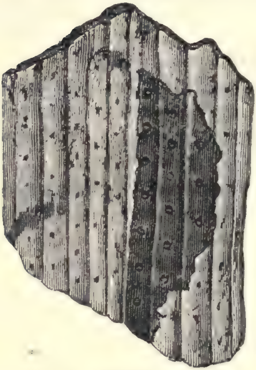


FIG. 132.—Sigillaria organum.

About forty species in the coal formation.*

Volkmannia. — Stem striated, articulated; leaves collected in approximate, dense whorls. These are considered to be, probably, the leaves of *calamites*.

Carpolithes.—Under this name are arranged all the fossil fruits to which no other place is assigned.†

ARRANGEMENT OF THE PLANTS OF THE COAL. — The most common of the coal plants may be classified under the following divisions: — First, ferns and *sigillariæ*. Secondly, *lepidodendra*, a doubtful genus, provisionally referred to *lycopodiaceæ;* but, by Corda, ascribed to *crassulaceæ*. Thirdly, *calamites*, allied to *equisetaceæ*. Fourthly, coniferous plants. Fifthly, *stigmariæ*, which appear to be an extinct family.

I. FERNS AND SIGILLARIÆ.—The leaves of flowerless plants differ from true leaves in many particulars, and are therefore called fronds. The genera of fossil ferns have been determined by the characters of these fronds, such as their mode of attachment to the *rachis* or stem, their shape, their method of branching, and the way in which the veins are distributed.

* Pict. Atlas, pl. xix., xx., xxiv., p. 200, figs. 3, 4, 5, and 6.
† Pict. Atlas, pl. xxxiii.

The student will find it necessary to devote particular attention to the fossil ferns, to enable him to discriminate the different genera and species. The four genera which most nearly resemble each other are *neuropteris, sphenopteris, pecopteris*, and *odontopteris*.* The following may be mentioned as distinctive characters. *Neuropteris* is known from *sphenopteris* by its leaves being cordate at the base, while this character is reversed in *sphenopteris*, in which, near the base, the leaves are usually smallest; the shape of the leaflets is moreover different, those of *sphenopteris* being lobed, while those of *neuropteris* are not. *Pecopteris*, again, is distinguished from *neuropteris* by its leaves being occasionally tripinnate, which is never the case with *neuropteris;* the midrib of *pecopteris* also runs quite through the leaflet, while in *neuropteris* it vanishes at the apex: the veins, moreover, of *pecopteris* run almost perpendicular to the mid-rib; while in *neuropteris* they are oblique and curved; and the genera *odontopteris* and *neuropteris* are distinguished from each other by the veins of the former proceeding into the segments directly from their base, without collecting into a distinct mid-rib, and by those of the latter gradually diverging from the mid-rib, as they approach the point of the segments.

We subjoin a magnified leaf of a common species of each genus; and for farther particulars, such as the form, mark-

FIG. 133.—1. Neuropteris. 2. Sphenopteris. 3. Pecopteris. 4. Odontopteris.

ings, and other characters of recent leaves and stems, analogous to those of fossil specimens, we again refer our readers

* Pict. Atlas ɒl. iv.

to the splendid work of M. Brongniart, from which the preceding figures are taken (fig. 133).

SIGILLARIÆ.—The same deposits of the coal afford numerous fluted stems, or trunks of trees, which, when they occur in the shale, are usually flattened by the pressure of the superincumbent strata, but when placed vertically or obliquely in the grit, or sandstone, are round and uncompressed. From presenting small impressions, occasioned by the decay and fall of the leaf-stalks, resembling markings made by a seal, they have obtained the name of *sigillariæ*. They have also been figured and described by various writers on Fossil Botany, under the names of *rhytidolepis*, *alveolaria*, *favularia*, *catenaria*, &c. They have hitherto been considered as monocotyledonous plants; but later observers, particularly the late Mr. Bowman, in a communication to the Geological Society, on the fossil trees, discovered on the Bolton Railway,* endeavours to show that the *sigillariæ* belonged to the dicotyledonous division. He founds this conclusion on the following evidence:—

The irregular, longitudinal and discontinuous, or anastomosing furrows on the surface of the stems; the swelling out of the stems at their base; their angle of dip, or downward direction of the roots; characters which, he observes, are constantly observable in dicotyledonous, but never in monocotyledonous plants. He adduces marks of striæ as proving that these trees have a separable bark, and finally, in slices of a tree of this kind, prepared for microscopic investigation, he discovered traces of medullary rays, which are universally recognised as indisputable proofs of dicotyledonous structure. The supposition that these plants were hollow, a circumstance which would be fatal to their dicotyledonous character, had previously been denied by Mr. Hawkshaw, who had stated that in tropical climates the interior of solid hard-wood trees is often consumed by insects, in an extremely short space, leaving the bark intact, and the tree apparently sound. Hence it is inferred, that in the ultra-tropical climates of the carboniferous epoch, solid trees might have been internally destroyed, and rendered hollow in a short period of time.

While the *sigillariæ* are thus generally regarded as dicotyledonous, or exogenous trees, Dr. Lindley has divided from

* See Proceedings, vol. 3, No. 63, p. 273.

them another genus termed *caulopteris*, which he considers as true stems of tree-ferns. They are hollow; but the markings which they exhibit present so close a resemblance to existing tree-ferns, as to render their identity with those plants highly probable. They are, however, comparatively rare, while of *sigillaria*, forty species have been discovered in the coal. Figures of the fossil stem, *caulopteris* (fig. 134), and of that of a familiar species of recent fern (fig. 135), are placed in juxtaposition for comparison.

Fig. 134.—Caulopteris Phillipsii, Lindley and Hutton.

Fig. 135.—Stem of recent tree-fern.

II. Lepidodendra.—These are a very numerous class of fossils from the coal. They have hitherto been conjectured to be referable to the family of club-mosses, and the larger species were regarded as forming a transition to the coniferous plants. The living species (fig. 136) of their supposed analogues abound in tropical climates, they generally creep on the ground, some grow erect, but none exceed three feet in height; whereas fossil specimens have been found thirty feet high, while fragments have been discovered indicating a much larger size (fig. 137 and 138.)*

Fig. 136.

* See the references to the plates of this group, p. 189.

Professor Corda, of the Bohemian National Museum at Prague, in his work above mentioned, *Skizzen der vergleich-*

FIG. 137.—Branching Trunk of L. Sternbergili, Foss. Flo. 203.

FIG. 138.—Branching Stem, with bark and leaves, *Flora der Vorwelt, Erstes Heft*, Leipzig, 1820. Pl. II.

enden Phytotomie vor-und jetztweltlicher Pflanzen-Stämme, or Sketches of the Analogies of Structure in the Stems of recent and fossil Plants, p. lxxi., refers them to a totally different family. He declares that both in general habit, and external and internal structure, they are far more closely allied to the existing *crassulaceæ* than to any other tribe, and that both in external and internal characters they are strongly distinguished from *lycopodiaceæ*. With regard to the *lepidostrobi*, he observes that they have never yet been proved to be the fruit of *lepidodendron;* and he considers them the male flowers (*die männlichen Blüthen*) of a plant of the fir tribe.

The *crassulaceæ*, or house-leek family, comprises 272 species, of which 133 are found at the Cape of Good Hope, 52 in Europe, and the remainder in various regions, chiefly those of the temperate zone. They occur in the driest situations, where not a blade of grass nor a particle of moss can grow, on naked rocks, old walls, or hot sandy plains, alternately exposed to the heaviest dews of night, and the most intense

rays of the noon-day sun. Soil is to them a something to keep them stationary, rather than a source of nutriment, which in these plants is conveyed by myriads of small cuticular pores to the cellular tissue which lies beneath them. The accompanying is a figure of a typical species of this family (fig. 139).

FIG. 139.—Crassula tetragona, from De Candolle's *Plantes Grasses.*

III. CALAMITES. — These have already been described as allied to the *equisetaceæ*, or horse-tail tribe; but they differ in their much larger size, the analogous plants in these regions being only two feet high, while a gigantic species of the tropics is no more than five feet in height, and an inch in diameter; whereas their fossil representatives far exceed these dimensions, both in circumference and elevation; they were farther distinguished by having a thin bark, and are now generally considered a separate and extinct family.*

IV. THE CONIFERÆ.—It has been observed, as a remarkable circumstance, that the fossil *coniferæ* of the coal bear a close resemblance to those of the existing genus *araucaria*, or Norfolk Island pine; slices of the wood, when examined by the microscope, showing that the ducts or glands peculiar to this family are arranged in a similar manner; that is, alternately in double and triple rows (fig. 140).

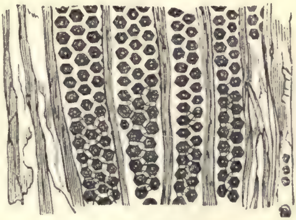


FIG. 140.

V. STIGMARIÆ. — These have recently been most ully and ably described by

* Pict. Atlas, pl. xv., xvi., xvii.

Mr. Logan, in a valuable contribution to the Geological Society,* As the paper will be again cited, in treating of the coal formations, we shall merely remark that the author adopts the idea of Mr. Steinhauer, that the *stigmaria* was a large, succulent water-plant, the stem, in its compressed fossil state, varying from two to six inches in diameter, and having numerous processes,† which proceed vertically, horizontally, and obliquely, and traverse the beds in every direction. These processes have been traced to a distance of eight or ten feet from the stem, and had a horizontal range of twenty feet. From the number of these plants, it is concluded that they have furnished the material for the great mass of our beds of coal, and from their constant presence in every seam over the whole area of South Wales, is derived evidence of the most conclusive character, that the coal was formed by submergence on the spot, and not by drift, as heretofore supposed.‡

For more complete details, explanations of technical terms, &c., the student is referred to the elementary works

FIG. 141.

FIG. 142.

on botany already mentioned. As the leaves, however, constitute a highly important feature in this department of science, we shall here introduce a few remarks descriptive of their characters, as they occur most commonly in fossil plants.

Leaves are either *simple*, consisting of one leaf, as in the lily; or *compound*, composed of several leaflets, as in the rose. *Compound* leaves are distinguished into *pinnate*,

* See Proceedings, vol. 3, No. 69, p. 275. † See fig. 101.
‡ Pict. Atlas, pl. xxi., xxii., xxiii.

bipinnate and *tripinnate;* and into *ternate*, *biternate*, and *triternate*, &c.

A *pinnate* (or winged) leaf, is one, the stem or foot-stalk of which has several leaflets at each side, growing, at equal distances, in pairs. (Fig. 141.)

A *bipinnate* leaf is one in which the footstalk itself is divided, and branches out into other footstalks, each of which supports leaflets, corresponding in all their modifications to those of the simply pinnate leaf. (Fig. 142.)

A *tripinnate* leaf is of the same description as the above, once more decompounded: the footstalk being *bipinnate*, and supporting leaflets, as in the former modes. (Fig. 143.)

The term *ternate*, with its compounds, indicates an analogous arrangement. A *ternate* leaf is so called when the footstalk supports three leaflets (Fig. 144);

FIG. 143.

FIG. 144.

a *biternate* leaf is when the common footstalk supports three others, each of which supports three leaflets (fig. 145); and a *triternate* leaf is only a farther decomposition of the above. (Fig. 146.)

A *pinnatifid* leaf is one which is cut transversely into several oblong, parallel segments (fig. 147); and *bipinnatifid* denotes another decomposition of the same form. (Fig. 148.)

As to position, leaves are either *radical*, that is, proceeding from the crown, or radical plate; or they are *caulinar*, borne on the stem; and either *sessile* or *petiolate*, that is, either sitting or having footstalks. Sessile leaves are sometimes *vaginant*, that is, sheathing, as in grasses; or *amplexicaule*,

stem-clasping, as in many umbelliferous plants; or *connate*, situate opposite each other, and united at the base, circum-

FIG. 145.

FIG. 146.

scribing the stem, as in the leaves of the honeysuckle; or they are *decurrent*, running down the stem, &c., &c.

FIG. 147.

FIG. 148.

As regards shape, their modifications are innumerable; the chief of these, as regards fossil plants, are as follows:— They are *linear*, narrow, and long, with parallel sides, and of equal breadth throughout; or *lanceolate*, of a narrow, oblong form, tapering towards each end; *verticillate*, growing in rings or whorls; they are, farther, *ovate*, egg-shaped; *obovate*, the same form with the large end upwards; *cordate*, heart-shaped, *obcordate* the heart-shape reversed; *hastate*, spear-shaped; *auriculed*, having appendages like ears; *lobed*, with the margins of their segments rounded, while, according to the number of lobes, the leaf is termed *bilobate*, *trilobate*, &c.; they are *adherent* or not *adherent* to the stem, or to

each other; they are *deciduous*, or withering and falling; or *persistent*, remaining; they are *flabelliform*, or fan-shaped; or *imbricated*, placed one over another, like the tiles of a house. They are also *succulent*, soft and juicy, *coriaceous*, resembling leather, &c., &c.; the *areolæ* are the spaces from which the leaves have fallen.

Venation constitutes a highly important character in fossil botany, since the veins often afford very conclusive evidence as to the generic character of a plant. The *costa* is the mid-rib from which the smaller veins usually proceed; these are *simple*, (that is, undivided,) or *dichotomous*, (forked,) once, or more than once; *anastomosing* (running into each other); *reticulated*, forming a net-work; or *radiating*, proceeding from a centre, like the spokes of a wheel, &c., &c. See Dr. Lindley, Sir J. E. Smith, Sir W. Hooker, &c., &c.

EXERCISES.

ON FOSSIL BOTANY.

1. Describe the arrangement of plants according to the natural system of Jussieu.
2. Explain the term, cotyledon.
3. Describe the monocotyledonous and dicotyledonous divisions of plants.
4. Show the difference of the two classes, as developed in the seed, the wood, and the leaf.
5. Describe the successive epochs in the Flora of the ancient earth, as proposed by Brongniart, and modified by Sternberg.
6. Name the six divisions of the vegetable kingdom adopted by Brongniart.
7. Copy and commit to memory the eighteen families which form the six divisions above stated.
8. State the experiment of Dr. Lindley, as to the power of certain plants to resist decomposition in water, and its results, with the remarks of Count Sternberg.

9. Describe the nature of the flora of the ancient earth, and the peculiar climate indicated by such a character of vegetation.

10. State the period when this flora gradually assumed its present European character.

11. Commit to writing a list of the genera of fossil plants, with the derivation of their respective names.

12. Copy, on tracing paper, a typical specimen of each genus.

13. Seek to combine practice with theory, and identify specimens of each genus with their description in books.

14. Name the genera which most closely resemble each other, and state the characters which distinguish *odontopteris* from *pecopteris*, and the latter from *neuropteris* and *sphenopteris*.

15. Trace the leaves (with their venations) figured in page 197.

16. Trace in like manner a pinnate, bipinnate, and tripinnate, and a ternate, biternate, and triternate leaf.

17. Trace from the work of Brongniart the leaves (with their venation) of recent ferns resembling the fossil species.

18. State the distinction between *caulopteris* and *sigillaria*, and the reasons for establishing the former as a separate genus.

CHAPTER VIII.

PALÆONTOLOGY.

Collections:—Royal College of Surgeons, British Museum, Economic Geology, Geological Society.

Authors:—Cuvier, Grant, Owen, Mantell, Buckland, Goldfuss, Pictet, D'Orbigny, Röemer, Vogt, Zieten.

PALÆONTOLOGY * may be defined to be the *science of fossil animals.* It comprehends all questions which connect these organisms, directly or indirectly, with the strata in which they are found, the conditions in which they lived, the changes by which they became extinct, and the mode through which their remains have been preserved.

By a careful study of organic remains, the palæontologist is enabled to determine the gaps that exist in the regular succession of families and genera, and by their presence or absence in particular rocks he ascertains the relative ages of different strata, and from their position and mode of preservation describes the disturbances and dislocations to which they have been exposed.

As the physiological laws which regulate the form, growth, and development of animals, have ever been the same, from the first dawning of life upon the surface of our planet, down to the present time, the means which the zoologist employs to distinguish and arrange existing species are alike applicable to the deciphering and classification of extinct forms; and as the distribution of animals and plants on the surface of the earth is determined by physical geography and climatology, so, in like manner, have the same physical causes

* (Gr. παλαιὸς, ancient; ὄντας, beings; λόγος, a discourse)—the history of ancient extinct organised beings.

influenced the grouping and distribution of extinct faunas and floras in former periods of its history.

The preservation of the generic and specific characters of fossil remains varies in different strata; hence arise many of the difficulties which beset the investigations of the palæontologist, and warn him against a too common error of drawing hasty generalisations from incomplete and imperfect data.

Many fossil remains are preserved as complete and perfect for scientific investigation as the bodies of living animals. For example, the elephant and rhinoceros, with their muscles, skin, and hair preserved by the antiseptic power of cold in the frozen drift of Russia and Siberia; or the skeletons of chelonian and saurian reptiles interred in the oolitic, cretaceous, and tertiary rocks.

Most of the fossil shells of the tertiary period, with the exception of their colours, have their specific characters as perfectly preserved as those of our present seas. In many of the secondary and palæozoic rocks, they are likewise found in great perfection; whilst in other strata the existence of these organisms is determined by casts of the inner surface of the shell, or by moulds made in the solid rock; the calcareous material of the shells having been subsequently removed by chemical action.

The horny and calcareous skeletons of articulated animals are sometimes preserved entire; as insecta in amber, and crustacea in the palæozoic, secondary, and tertiary rocks.

The complicated skeletons of radiated animals are found interred in strata of different ages; and the minute details of the structure of this group are so perfectly preserved, that the fossil species of Crinoid, Asteroid, and Echinoid radiata, are described with as much rigorous accuracy as the existing species of these orders.

The numerous remains of delicate polypiferous zoophytes, which are strewed among rocks of all ages, are preserved with wonderful perfection, and indicate, in some instances, the former existence of coral reefs in the seas of the silurian and oolitic periods; whilst the microscopic organisms that have left their siliceous shields in the tertiary beds attest, to the observer of Nature's minute works, how permanent are the specific characters of the world that lies beyond the ken of the unaided eye of man.

Each of the periods into which the palæontologist divides the history of the earth, is characterised by a distinct suite of organic remains. Thus the mollusca, crustacea, and fishes of the palæozoic rocks, differ from those of the secondary series. The fishes and reptiles of the oolitic and cretaceous periods are different from those of the tertiary. The speciality of fossils is not limited to families and genera, but extends even to the species of the animal series, so that a practised eye can at once determine to which stage of any system of rocks a given suite of fossil remains belong.

From the period this great fact was first enunciated, down to the present time, it has received from each succeeding palæontologist some important additions; but by none has its details been developed with so much patient research, and illustrated with such scientific precision, as by Alcide D'Orbigny, the learned and accurate author of the "Paléontologie Française," to whose works we must refer the student for ample details on this most interesting branch of inquiry.

The association of certain species of fossil animals in each chapter, so to speak, of the history of the earth's crust, has demonstrated the existence of a series of distinct faunas, from which the palæontologist has inferred the existence of certain laws which appear to have governed the same. His generalisations, it is true, are not unexceptionable; still they have contributed to the progress of science, and have called the attention of naturalists to many interesting and important questions that have arisen in the study of organic remains.

The five principal laws which have been established relative to the question of successive faunas, have been well explained by Professor Pictet, in his valuable work,* to which we refer for further details.

First Law.—*The species of animals of one geological epoch lived neither before nor after that epoch, each formation has its own fossil species, and the same species is never found in two strata of a different age.*

Although the generality of this law is not admitted to the

* Traité Elémentaire de Paléontologie, tom. i. p. 56.

same extent by all palæontologists, it is nevertheless one which the progress of science has shown to be more general than was at one time supposed. The actual state of our science does not permit us to affirm that this law is without exceptions, but all the probabilities accord in favour of the speciality of fossils. "All the works that have been written by zoologists well acquainted with the discrimination and precision which palæontology requires, have almost invariably given as their result that fossils are different in each formation." *

If we take, for example, the fossils of the triasic, oolitic, and cretaceous periods, we find them to be completely different from one another; but it is probable that future investigation will show that we must go much further than this, and admit that the stages or sub-divisions of each of these periods possess their own special fauna. D'Orbigny has shown,† that in the chalk rocks of France no species of fossil molluscan or radiate animal is common to any two of the stages into which he has sub-divided the cretaceous system of that country. That is to say—

The cretaceous period is divided into seven stages,‡ the	Danien Sènonien Turonien Cènomanien Albien Aptien Nèocomien	Each of these stages he has found contains its own special fauna.

SECOND LAW.—*The differences which exist between extinct faunas and living animals are greater in proportion to their antiquity;* or, in other words, in the same ratio as the sedimentary strata are more ancient, the animal debris contained therein differ from the forms that inhabit the earth at the present day.

This law becomes evident when we compare the fossil remains of animals of different geological epochs. If, for example, we examine the shells of the tertiary strata, we shall recognise in its newer divisions a majority of forms

* Pictet, p. 64. † D'Orbigny, Paléontologie Française. Ter. Cretacé.

‡ For the English equivalent of these stages, see the table in the chapter on the cretaceous group.

with which we are familiar; whilst, if we study the Eocene fauna, the new and unknown forms which we encounter of extinct species become much more frequent. On this fact is based the per-centage classification of the tertiary rocks, proposed by M. Deshayes and Sir C. Lyell.

THIRD LAW.—*The comparison of faunas of different epochs shows that the temperature of the surface of the earth has been greatly varied.*

The facts upon which this law is established are these. We find fossil animals in regions of the globe which are not inhabitable by them at the present day, in consequence of their low temperature, as the rhinoceros and elephant, which lived under the latitude of the glacial sea. This region could not, in our time, furnish a vegetation fit for the support of these pachydermata.

The fauna of the tertiary period, in Europe, presents a greater analogy to the animals of the torrid than to those of the temperate zone. The remains of the vegetable kingdom may be cited in confirmation of this law. Europe was, during the carboniferous period, covered with an immense vegetation, which for luxuriance, and the character of the vegetable tribes of which it was composed, can only be likened to that which exists in the present inter-tropical regions of the earth.

FOURTH LAW.—*The species which lived in the ancient epochs had a more extended geographical distribution than the species which exist in our day.*

This law has not been clearly demonstrated, nor can it be definitely admitted until the numerous localities have been studied, and their fossils determined with sufficient accuracy.

The observations which appear most worthy of belief tend to show that we find, in contemporaneous strata, some species which are common to Europe and to America. Other observations prove that the species which inhabited the greater part of Europe, during the periods anterior to ours, had a wider geographical range into the Asiatic continent and boreal region, than the species which inhabit Europe at the present day.

Should these facts receive confirmation by subsequent investigation, we shall be enabled to deduce some interesting consequences on the state of the globe during the different epochs of its history.

The four preceding laws seem to be established on sound premises; but that which remains to be enunciated must be received with considerable reservation, as it involves the right interpretation of physiological questions which are far from being clearly understood.

FIFTH LAW.—*The faunas of the most ancient strata are composed of animals of a more simple organisation, and their degree of perfection increases in proportion as we approach epochs more recent.*

In the brief space allotted to this chapter, it is impossible to discuss this law on its merits; and therefore we must refer to Pictet's admirable work for an exposition of this branch of the subject. It may be observed, however, that if the law is limited to the grouping of species, or the numeric proportion between the vertebrate and invertebrate animals, then it is true that the absence of the higher organisms from the ancient rocks supports the correctness of the proposition. But if this fact is mixed up with theoretical ideas on the progressive development of species, through long periods of time, then it becomes a question of hypothesis, and ceases to be one of sound deduction.

The animal kingdom is divided into four great groups:—

1. RADIATA.
2. MOLLUSCA.
3. ARTICULATA.
4. VERTEBRATA.

This division is based on the structure, development, and mode of arrangement of the nervous system, to which the dermal * and osseous skeletons may be considered as the appanage. It is, therefore, a strictly natural grouping of the primary forms of animals.

We shall pass in review each of the classes to which fossils belong, commencing with the lowest and ascending to the highest.

* (Gr. δερμα, skin) belonging to the skin.

FIRST DIVISION.

RADIATA, *Cuvier*. CYCLO-NEURA, *Grant*.

Body, circular or rayed; skeleton, simple or complicated; nervous system, when present, in the form of a knotted filament, encircling the entrance to the stomach. It comprises five classes:—

1. *Spongiaria.*
2. *Polypifera.*
3. *Infusoria.*
4. *Foramenifera.*
5. *Echinodermata.*

The SPONGIARIA are among the lowest forms of animal life. They are composed of a horny framework, invested with a simple gelatinous tissue, and furnished with vibratile cilia, for causing currents of water to flow through their porous structure; the horny network is consolidated with silicious or calcareous spiculæ. The spongiaria remain rooted to rocks at the bottom of the sea, or hang like living stalactites from the vaulted arches of submarine caves; or their delicate vegetable forms droop in endless variety from the shelving edges of rocks exposed to the washing of the surge. They are reproduced by small gemmæ, covered with cilia, which are free organisms during the first period of their existence. We form three orders of this class: the first have *silicious* spiculæ, the second *calcareous* spiculæ, and the third have a *horny network* without either. Fossil sponges are found in most strata, either entire or decomposed into spiculæ. Most of the extinct species are fossilised with silex, which permeated their structure in a fluid state, as it has either enveloped the body of which it retains a cast, or has flowed into all the textures of the organism and preserved a silicious model of its anatomy. To account for the immense accumulation of flints in the upper beds of the white chalk is one of the unsolved problems of geology. These flints nearly all contain the remains of fossil spongiaria. The fibrous internal struc-

ture of the sponge is indeed not always preserved, but the general form—the sessile or spreading character—is retained—and in some the vents and pores are exhibited. Like the bodies of recent Spongiaria, these silicious fossils contain Infusoria in their interior; and sections of flints prepared by the lapidary, and mounted on glass slides with Canada balsam, exhibit their microscopic forms in great perfection. The spiculæ of fresh-water sponges are found in great profusion in lacustrine tertiary beds, along with the shields of fossil infusoria. Many of the moss agates are of spongious origin; and the beautiful sections cut from the pebbles of

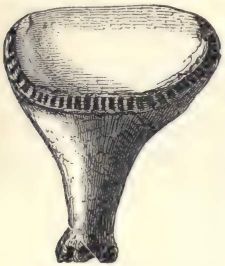


FIG. 149.—Ventriculite silicified.

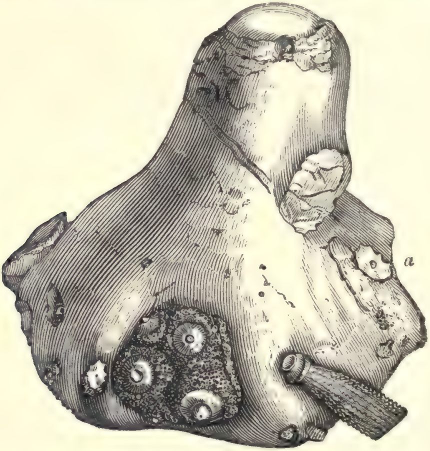


FIG. 150.—Silicified Spongiaria from the Kentish chalk.*

the Sussex coast, and those of the Isle of Wight, owe their

* Fig. 150.—Flint, with plates and spines of *Cidaris* embedded whilst the silex was fluid.

exquisite markings to the fossil *Choanite* * and other Spongiaria which they contain.

In addition to these, the *Ventriculites*† from the chalk (fig. 149), the *Siphonia*‡ from the green sand, and the variety and beauty of the different Spongiaria from the same stratum, near Farringdon, in Berkshire,§ are familiar examples of the fossil remains of this class.

Polypifera.—The elegant plant-like zoophytes, that convert the bed of the ocean into a garden of animal forms,

Fig. 151.—Corallium rubrum, and Magnified Branch.

adorned with the most rich and varied hues, but for ever

* Pict. Atlas, pl. xlii. † Pl. xli. ‡ Pl. xlii. § Pl. xliii., xliv., xlv.

rooted by a calcareous base to some sub-marine body, constitute the class Polypifera. Their skeleton assumes a vast variety of forms, being horny or calcareous, globular or branched, solid or tubular, stellate, porous, or reteform. The gelatinous organised substance of the animal is enclosed in ramified tubular sheaths, or expanded over the surface of the calcareous skeleton which it encloses and secretes. The mouth of the polyp is surrounded with numerous filaments or tentacules, which, in the highest groups, are furnished with vibratile cilia. Each polyp, or digestive sac, contributes a moiety to the nourishment of the compound body with which it is organically united. This physiological relation occasions remarkable associations and singular groupings among the Polypifera; hence the stupendous results obtained from their operations in the seas of inter-tropical regions, by which the life of the individual is combined with the life of the whole, and the nutriment prepared by each organism is made to contribute to the nourishment of the community, of which it forms a part, as in the red coral, fig. 151.

The calcareous skeletons of some *Anthozoa* are very abundant, and attain a great magnitude in the Pacific, where they may be said to modify the ocean's bed, and contribute largely to the formation of new continents. That there are masses of rock many leagues in extent, founded in the recesses of the ocean, and built up into gigantic structures, from eight hundred to a thousand feet in thickness, by the secretions of polyps, is a fact of deep interest to the naturalist, and of great importance to the geologist, the study of which affords him important data for reasoning on the operations of these animals in former periods of the earth's history. Dr. Darwin * has recently shown that the zoophytic productions known as coral reefs, and coral islands, may be classified into three groups—Atolls, Barrier-reefs, and Fringing-reefs; that the vital operations of the Polypifera are limited within the range of thirty fathoms, and that beyond that depth they cannot live; that the forms which reefs assume depend upon the elevation or subsidence of the ocean's bed, on which the foundations of the zoophytic structure are laid. These facts, previously ascertained by Quoy, Gaymard,

* On the Structure and Distribution of Coral Reefs, 8.—1842.

Stutchberry, Ehrenberg, and Beechey, and now confirmed by Darwin's observations, enable us to reason more correctly on the importance and extent of the labours of Polypifera in relation to the history of the earth itself, and of the higher classes of the animal series: for when we compare the stupendous results obtained by the operations of a community of polyps with the boasted monuments of man, the latter sink into insignificance. The great wall of China, or the pyramids of Egypt's plains, are as nothing when contrasted with the barrier-reefs that stretch along the shore of New Caledonia to the length of four hundred miles, or those which run along the north-east coast of Australia for upwards of a thousand miles.

How marvellous is the reflection, that these masses of calcareous rock have been secreted, through successive ages, by generations of tiny architects, amidst the waters of the ocean, and in defiance of the violence of its ever restless waves!

The study of such phenomena prepares the mind of the geologist for the investigation of operations of a similar character which have taken place in the seas of former periods of the earth's history. Many palæozoic and oolitic rocks may be said to be ancient coral reefs, and appear to have been formed under conditions analogous to those which are now in progress in the waters of the Pacific.

We divide this class into two orders—

BRYOZOA—ANTHOZOA.

The BRYOZOA includes the most highly-organised Polyps. The tentacula are ciliated; the digestive organs have an intestine and rudimentary gland; the body has no septal divisions, and they possess a type of structure which connects them with some of the Molluscan class. This order includes the families ESCHARADÆ, TUBULIPORIDÆ, MYRIOPORIDÆ, ASTERODISCIDÆ, ANTIPATHIDÆ.

The ANTHOZOA have unciliated tentacula, no intestinal appendage to the stomach, and have the body of the polyp divided by septa, which produce stellate laminated cells on the polypary.

The cells seen on the surface of *Astrea*, *Madrepora*,

Caryophyllia, *Meandrina*, and other cognate genera, are produced by the calcification of the septa of the body.

As the polyparies of this order are more solid and massive, and their characters are better defined, they are of more importance to the palæontologist, but we must caution the student against the supposition that they are easily identified; on the contrary, it requires much patient study and accurate observation to become acquainted with the fossil genera.*

We separate the Anthozoa into two sub-orders—Zoo-corallina and Phyto-corallina. The following table gives a general idea of the families :—

ANTHOZOA	Zoo-corallina	FUNGIADÆ
		TUBIPORIDÆ
		ALCYONIDÆ
		PENNATULIDÆ
		TUBULARIDÆ
		SERTULARIDÆ
	Phyto-corallina	OCELLIDÆ
		ASTREADÆ
		MADREPORIDÆ
		MILLEPORIDÆ
		ISIDÆ
		GORGONIDÆ.

The palæontological history of this class proves that each

A

FIG. 152.—*Litharœa Websteri* from Bracklesham Bay.

period has generic and specific forms special to it: that the

* For British Corals, consult Professor Milne Edwards' Monograph, and Pictorial Atlas, Pl. xxxiv. to Pl. xl.

corals of the Silurian period do not all belong to the lowest forms, but, on the contrary, that many of them have the Bryozoan type of structure; a fact which we shall hereafter connect with others of a like character, derived from an investigation of the higher classes of the animal series. The subjoined figures (152 and 153) of a beautiful Anthozoan coral (*Litharæa Websteri*), from the tertiary sands of Bracklesham Bay, may be regarded as typical of the polypifera.

INFUSORIA.—The waters of every pond and rivulet, of every lake and river, together with those of the great ocean itself, swarm with innumerable minute forms of animal life, which, from the circumstance of their abounding in infusions of vegetable substances, have been called Infusoria. Many of these microscopic organisms, like the *Monas crepusculus*, measure only about the thirty-two thousandth part of an inch in length, and all are so minute that it requires the highest powers and the best object-glasses of the microscope to study their organisation and watch their habits.

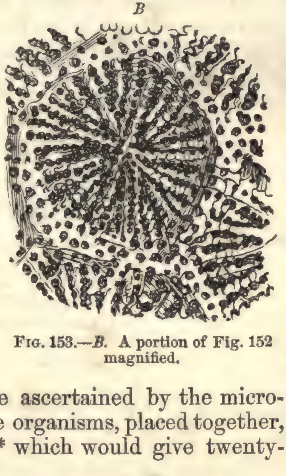


FIG. 153.—*B*. A portion of Fig. 152 magnified.

Professor Ehrenberg, the great historiographer of this class, has made some interesting calculations on the minuteness of some Infusoria. He ascertained by the micrometer that two thousand of these organisms, placed together, would measure about one line,* which would give twenty-four thousand in an inch.

In some infusions, certain species are crowded so closely together, that he estimated that ten thousand swim freely in that space; consequently, a cubic inch of such an infusion would contain more organised atoms than there are human beings on the surface of the earth. When we reflect upon the universal distribution of the Infusoria in the waters of our planet, as well as in the juices of animals and plants, we cease to be astonished at their omnipresence in nature, and

* A line is one twelfth of an inch.

learn to adore with humility the goodness of their Divine Author, who in the earth and in the heavens has shown to inquiring man that his works are as infinite in extent as they are all-perfect in structure.

As every improvement in the construction of the telescope has rewarded the astronomer with some new discovery in the architecture of the heavens, so, in like manner, has every addition to the power of the microscope introduced the naturalist to new forms of existence in the organisms of the earth.

Some families of Infusoria are enclosed in silicious shields, marked with longitudinal, transverse, or oblique lines, or adorned with various other forms of sculpture.

Many genera of these loricated organisms belonging to the families BACILLARIDÆ and PERIDINIDÆ have been found in a fossil state in the tertiary deposits of Europe and America. The following table exhibits the principal genera:*—

BACILLARIDÆ	*Pyxidicula*	Silex, Berlin.
	Xanthidium	Silex and in chalk.
	Gallionella	Tripoli, Bilin, Farina, Finland.
	Actinocyclus	Tripoli, Oran.
	Navicula	Tripoli, Germany, Farina, Sweden.
	Eunotia	Farina, Tuscany, Sweden, Finland.
	Coconeis	Tripoli and Farina.
	Bacillaria	France, Germany, England, America.
	Synedra	Farina, Tuscany.
	Podosphenia	Tripoli, Bilin.
	Gomphonema	Farina, Tuscany, Finland.
	Coconema	Tripoli, Farina.
	Achnantes	Farina, Finland.
PERIDINIDÆ	*Chetotyphla*	Silex, Delitzch.
	Peridinium	Silex, Delitzch.

The palæontological history of this class commences with the discovery by Ehrenberg that the substance known as *Tripoli, polirschiefer* of the Germans, was composed of the silicious shields of many of the above genera. Subsequent observations made by microscopists have shown that most of the tertiary deposits in Europe and America contain a vast accumulation of these microscopic fossils.

Ehrenberg estimated that a cubic line of the *polirschiefer*

* We have no doubt that many of these belong to the *Desmidiæ* and *Diatomaceæ*.

of Bilin contained in round numbers 23,000,000 of individuals. As there are 1728 cubic lines in one cubic inch, therefore a cubic inch of the Bilin *polirschiefer* would contain $1728 \times 23{,}000{,}000 = 39{,}744{,}000{,}000$ fossil skeletons.

A cubic inch of this fossiliferous rock weighed 220 grains, so that each grain of Tripoli enclosed about 180,000,000 fossils; the weight of each fossil, therefore, would be about the $\frac{1}{180}$ millionth part of one grain.*

One of the most singular beds is that which has been called fossil farina, or *Bergmehl*, by the natives of Finland and Lapland, where it is found. This powder they mix with flour, and consider nutritious. The microscope shows that it is composed of the shields of Infusoria belonging to the genera indicated in the table.

These fossils are found likewise in opal and semi-opal, and in the South of Europe the chalk-marls have yielded numerous species. We have before us slides prepared with fossil

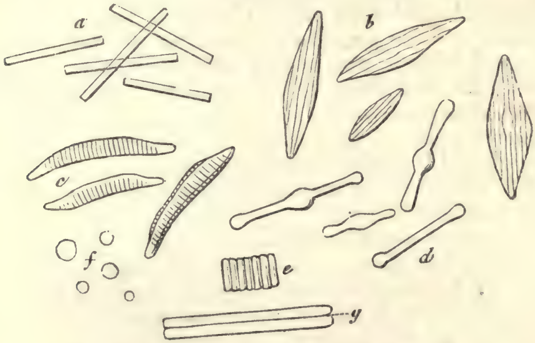


Fig. 154.—Magnified views of fossil infusorial remains.

Infusoria from Bann, in Ireland (fig. 154), and Dolgelly, N. Wales. We see their remains in thin slices of flint and marble, and numerous species are obtained from the chalk formation. So much have their remains contributed to the rocks of this period, that it is possible that on every glazed

* Taylor's Scientific Memoirs, vol. i. p. 407.

visiting-card we use in social life, we leave with our name some cretaceous Infusoria. Underlying the city of Richmond, in Virginia, is an extensive bed of fossil Infusoria, of the same genera as those now living in the Northern Seas.

It has been ascertained by Ehrenberg that accumulations of these microscopic beings are choking up the harbour of Wismar, in the Baltic, and that similar formations are effecting changes in the bed of the Nile at Dongola, in Nubia, and of the Elbe at Cuxhaven.

Foramenifera.—The singular organisms that form this class are microscopic animals of a simple gelatinous fleshy substance, without appreciable organisation, which secretes a delicate calcareous many-chambered shell, of extreme beauty, into the cells of which the body of the animal completely retires. The gelatinous fleshy material developes expansions, incessantly variable in form and completely retractile into the general animal substance, and which serve for swimming and for crawling.

These beautiful little animals are alike wonderful for the simplicity of their organisation, and for the variety, regularity, and delicate structure of their shell, many of which resemble those of the nautiloid molluscs. They are found in great abundance on the sandy shores of warm latitudes.

Plancus collected 6000 shells of Foramenifera from an ounce of sand from the shore of the Adriatic; and D'Orbigny found 3,840,000 in the same quantity of sand from the shores of the Antilles.*

So abundant are the remains of Foramenifera, that they form banks that blockade navigable channels, obstruct gulfs, and fill up harbours, and, aided by the incessant labours of polyps, they form at the bed of tropical seas the materials of future islands. Similar operations have taken place in former periods of the earth's history. Soldani † collected from less than an ounce and a half of rock from the hills of Casciana, in Tuscany, 10,454 shells of fossil foramenifera. Several of the species are so minute that 500 weighed only a grain, and others, more minute, would require double that number to make the same weight.

The *calcaire grossier* of France contains the shells of

* Pictet, tom. iv. p. 214.

† Saggio Orittografico, 1780, table iii.

foramenifera in great abundance; and in the tertiary sands of Bracklesham Bay (the English equivalent of this bed) we have found a profusion of the Parisian species. The subjoined figures of *Rotalia* are drawn from specimens found on the *Vermetus Bognoriensis*, by Mr. Wetherell, and described by him.*

FIG. 155.

The following figure represents *Rotalia* in flint from the chalk.

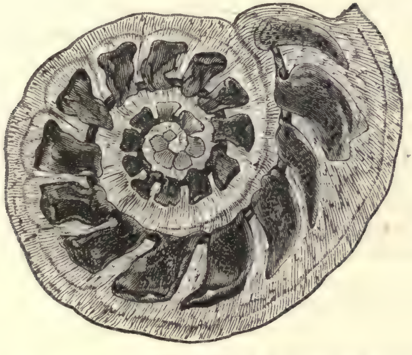


FIG. 156.—The Shell of a Rotalia, containing the fossilised remains of the body of the animal, in flint *highly magnified*.†

* Magazine of Natural History, vol. iii. p. 162.
† Mantell's Isle of Wight.

Their palæontological history is imperfectly known; about twenty species are found in the oolitic and cretacous rocks, referable to four genera; D'Orbigny has found in the chalk two hundred and fifty species, forming thirty genera; and in the tertiary beds four hundred and sixty species, belonging to fifty-five genera. Their greatest development has been reserved for the modern period, for the same author has found in our seas nine hundred species, belonging to sixty-eight genera.*

THE ECHINODERMATA.—This class forms the true type of the radiata, and is composed of animals, fixed and free, with a highly organised integument, for the most part armed with moveable spines. In the rayed families, the organs of locomotion are disposed around a central axis. In the spherical forms they are ranged in rows like the lines of longitude on a terrestrial globe, and the mouth and the anus are situate at the opposite poles. Each element of the body is in general repeated five times. Thus, the sea-lily has five primary arms; the sea-star, five rays; and the sea-urchin, five pairs of perforated, and five pairs of imperforated plates in its shell. The external surface of the skeleton supports a series of moveable spines, and the perforated portion gives passage to thousands of tubular feet for gliding over the bed of the shallow shores they inhabit. The three higher orders of this class, which have the holothuria, echinus, and asterias as their types, are free ambulatory animals, whilst the genera of the crinoid order are for the most part fixed by a calcareous stem like the polypifera. The higher forms possess visual organs. In the sea-star they are situate at the extremities of the rays. In the echinus, the mouth is provided with five complicated jaws armed with five long teeth, and the apparatus is moved by many pairs of muscles; the intestinal tube makes a tortuous course around the shell, and is maintained *in situ* by a delicate mesentery, and terminates at the upper pole of the sphere. In the sea-star, the stomach is a capacious sac, with glandular appendages which branch into each ray; and in the sea-lily it reposes in the calyx surrounded by the arms.

The echinodermata have a distinct system of vessels for the

* Pictet, tom. iv. p. 216.

circulation of the blood, and the highest order have a complicated branched tree-like organ for respiration. In other orders the water is admitted freely into the interior of the shell, and aërates the blood as it circulates through the body. The ova are developed in a long complicated ovary.

The class is divided into four orders—HOLOTHURIDA, ECHINIDA, ASTERIDA, CRINOIDA.

The HOLOTHURIDA (sea-cucumbers) have a soft contractile body enclosed in a muscular and coriaceous integument with tentacula around the mouth, and rows of tubular feet, disposed in longitudinal lines along the sides of the body. None of this order have yet been found in a fossil state.

ECHINIDA (sea-urchins) have a globular ovoid or depressed body without rays. Their shell is composed of a series of polygonal calcareous plates arranged in columns. One series of plates have their surface covered over with tubercles for supporting moveable spines. Another series have perforations for the passage of tubular contractile feet.

The mouth and the vent have distinct openings which occupy different relative positions on the shell; sometimes the vent is situated on the summit—sometimes on the posterior border—sometimes between the border and the summit—sometimes at the under surface of the shell, between the mouth and the border.

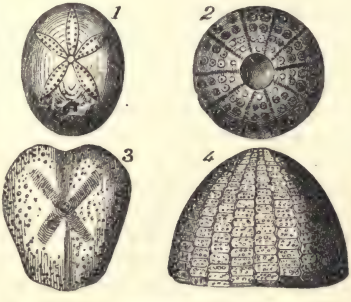


FIG. 157.—1. Nucleolites. 2. Cidaris diadema. 3. Micraster cor-anguinum. 4. Ananchytes ovata.

The Echinida is divisible into three families—the CLYPEASTROIDÆ, the SPATANGOIDÆ, the CIDARIDÆ.

Each family attained its greatest development at different periods.

The CLYPEASTROIDÆ, of which *Nucleolites* is typical, first appeared in the oolitic rocks; they are found in greatest numbers in the tertiary beds, and in our modern seas.*

* Pict. Atlas, pl. liv.

The SPATANGOIDÆ, of which *Micraster* and *Ananchytes* are types, appeared at the close of the oolitic, and attained a great development in the seas of the cretaceous period, the rocks of which contain a great variety of species very numerous in individuals.*

The CIDARIDÆ are the most highly organised, and, at the same time, the most ancient family.† They commenced in the permian group and the muschelkalk, lived in the seas of the lias, but had their greatest development in the oolitic period. Of all the echinidæ, this family has relatively diminished most in the tertiary and modern epochs.

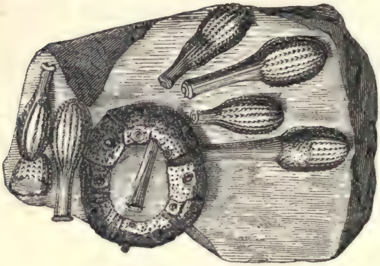


FIG. 158.—Cidaris margaritifera.

The ASTERIDA, or sea-stars, have a discoidal body composed of a central axis with branching moveable rays, more or less elongated, generally five in number, and either entire or branched. The skeleton is composed of many hundreds of calcareous pieces enveloped in an organised integument. The nervous system consists of a circular filament which surrounds the entrance to the stomach, and has a pair of ganglia, and a lash of nerves developed for each ray. The mouth is edentulous, inferior and central, and the body is free and ambulatory.‡

It comprises three families, two of which, the ASTERIADÆ and OPHIURIDÆ, are represented by a few species in the oolitic and cretaceous rocks.

The CRINOIDA, or sea-lilies, are thus defined by Millar:§ "An animal with a round oval or angular column, composed of numerous articulating joints, supporting at its summit a series of plates or joints, forming a cup-like body containing the viscera, from whose upper rim proceed five articulated arms, dividing into articulating fingers more or less nume-

* Pict. Atlas, pl. lv.
† Pict. Atlas, pl. liii.
‡ Pict. Atlas, pl. liii. fig. 3.
§ Natural History of the Crinoidea.

rous, surrounding the aperture of the mouth, situated in the centre of a plaited integument which extends over the abdominal cavity, and is capable of being contracted into a conic or proboscal shape."

The *Encrinus moniliformis* (fig. 159) from the muschelkalk, and the *Apiocrinites rotundatus* (fig. 160) from the Bradford clay, will convey an idea of the structure of this interesting order.

In the most perfect type of crinoidean the skeleton is composed of three distinct parts. The *root* (fig. 160), which fixes the animal permanently by a calcareous secretion to some sub-marine body: its form varies in the different genera. The *stem*, more or less elongated, is composed of calcareous pieces, piled on each other to form a flexible column for the support of the body and arms. The individual pieces are of a circular or pentagonal form. Their articulating surfaces are exquisitely sculptured of various

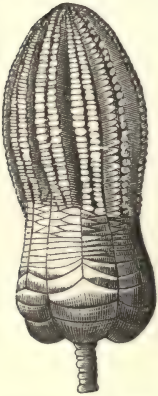


Fig. 159.—Encrinites moniliformis.

Fig. 160.—Apiocrinites rotundus.

figures which are permanent in the species, and afford characters for identifying the same. The stem in *apiocrinites* is cylindrical, slender in the middle part and enlarging

above. In *encrinus*, it is composed of different sized circular plates. And in *pentacrinus*, it is pentagonal. The *body* (figs. 159 and 161) resembles the corolla of a flower supported on a stem. It is composed of the cupula or calyx, formed of numerous plates united by their margins. To its upper surface the five primary rays are attached. They present a great variety of forms between the simple pinnate arms of apiocrinus and the complicated branched rays of pentacrinus—there is almost every grade of development.*

The arrangement of the plates in the structure of the body affords good characters for generic division. The parts now described do not exist in all crinoideans; thus, *comatula* has neither stem nor root, and in *marsupites*, (fig. 161) the cupula is in the form of a purse, composed of one central and three ranges of large polygonal plates. Each range having five plates, the central plate has no articulating surface for a stem, and the superior plates support the five arms.

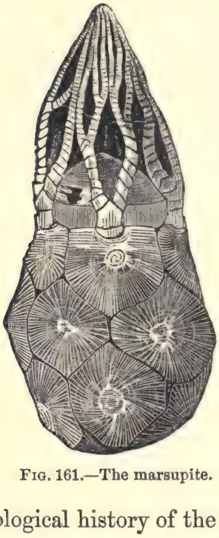


Fig. 161.—The marsupite.

This figure of *marsupites ornatus*, (fig. 161) from the Sussex chalk, exhibits one of those extinct crinoidea which formed the connecting link between this order and the genus *euryale*, one of the *asterida*.

The astrocrinida, echinocrinida, and the cystidæ possess a stem, but are destitute of arms; whilst in the typical genera these parts are all present.

The number of pieces required to compose the skeleton of the true crinoidea is very great; thus, Parkinson calculated that there were 26,000 separate elements in the skeleton of *encrinus moniliformis*; and Buckland estimates that there are above 150,000 elements in that of *pentacrinus briareus* of the lias. The palæontological history of the echinodermata presents us with some

* Pict. Atlas; beautiful figures of this interesting order are contained in plates xlvi. to lii.; see pl. xlvii. for anatomical details.

interesting facts. The different groups which compose this class, have had their principal development at very different epochs. The stalked *crinoidea* are extremely abundant in the palæozoic rocks: entire strata are in fact sometimes composed of the debris of their skeletons, and their ramose arms covered the bed of many an ancient sea. Their genera and species were greatly diminished in the triasic and oolitic periods. A few species are found in the cretaceous rocks, and they are represented in our modern seas by one rare species.

The *asterida* have an inverse history. We know a few species in the trias oolites and chalk, whilst the present seas of all latitudes abound with numerous species.

The *echinida* occupy an intermediate position between these extremes. They are rare in the primary epoch—increase in the trias—attain their maximum development in the oolitic period, and gradually decline in the cretaceous and tertiary strata.

SECOND DIVISION.

MOLLUSCA, *Cuvier*. CYCLO-GANGLIATA, *Grant*.

Body inarticulate, soft and pulpy, for the most part enclosed in a calcareous envelope or shell. Nervous system composed of ganglia dispersed through the body, and united into a circle by connecting filaments. The œsophagus surrounded by a nervous collar; the large ganglia reposing on this tube represent the brain. The encephalous orders possess organs of sense. Their blood circulates in a system of arteries and veins, aided by the contraction of a two-chambered heart. The terrestrial and most of the lacustrine species breathe by an air-sac or lung; and all the marine, and most of the lacustrine species, have branchiæ for respiration. Their shells are composed of a cellular albuminous membrane, indurated with the carbonate of lime, secreted by a portion of the tegumentary system, called the mantle. The shell is for the most part external, and presents a vast

variety of forms. Sometimes it is internal, and appears like a rudimentary bone. The mollusca are for the most part marine animals. Many are lacustrine, and a few are terrestrial.

The character of the shells varies with the habitat of the species. They are for the most part large and heavy in the marine, and light and delicate in the lacustrine and terrestrial species, although there are many exceptions to this rule.

The primary division of this class depends on the development of the nervous system, and on the presence or absence of the ganglia, that represent the brain. The first form the ENCEPHALOUS, the second the ACEPHALOUS section.

The ACEPHALOUS Molluscæ are all aquatic. Their distribution into classes depends on the character of the integument and the shell, and on the modifications of the respiratory organs; it consists of three classes:—

The *Tunicata* have no shell, and are enclosed in an elastic muscular sac, with two openings; some are solitary, others are social, and organically united in groups like polyps.

The *Brachiopoda* are enclosed in a bivalve shell. They have two long spiral arms developed from the sides of the mouth, and fixed to an internal frame work. They respire by means of the vascular membrane which lines the shell.

The *Conchifera* have a bivalve shell; they respire by laminated branchiæ, attached to, but distinct from, the mantle; most of them have a fleshy foot for locomotion.

The ENCEPHALOUS Molluscæ are divided into classes according to the modifications of the organs of locomotion.

The *Gasteropoda* are, for the most part, enclosed in a univalve shell. They creep by means of an undivided muscular disc or foot, situated on the under surface of the body.

The *Pteropoda* swim by two membranous wing-like expansions situated at the sides of the neck. When they have a shell it is thin, fragile, and univalve.

The *Cephalopoda* have all or part of their locomotive organs arranged round the head, in the form of eight or more arms or tentacula, with or without sucking discs.

Some have internal symmetrical bones, as the Sepia and Loligo. Others have an external, many-chambered shell, with a siphuncular tube passing through the chambers, like

the Nautilus. This multilocular dwelling is rolled into a variety of forms, being circular, scaphite, or turreted, in the different genera.

As it is most important that the student should possess clear ideas of the classes of the Mollusca, we have exhibited their most important characters in the subjoined table :—

The MOLLUSCA divisible into	The ENCEPHALOUS have	The body in the form of a sac, open before, from whence the head protrudes, surrounded by eight or more feet, or tentacula .		CEPHALOPODA.
		The body without feet, around the head; organ of locomotion in the form of	Membranous expansions situated at the sides of the neck . .	PTEROPODA.
			A muscular disc extended along the under surface of the body	GASTEROPODA.
	The ACEPHALOUS have	Four laminated branchiæ distinct from the mantle, and generally a fleshy foot		CONCHIFERA.
		No laminated branchiæ distinct from the mantle, and no fleshy foot .	Two long ciliated arms attached to processes on the inner side of the shell .	BRACHIOPODA.
			No spiral arms nor special organs for locomotion .	TUNICATA.

TUNICATA. In consequence of the absence of calcified parts in the *tunicata,* their remains have not been recognised in a fossil state. As the other classes of mollusca are nearly all enclosed in shells, these external skeletons are well preserved in the rocks of all periods, and form the most numerous and valuable groups of fossil remains.

The BRACHIOPODA, or arm-footed molluscs, are marine animals enclosed in bivalved shells, attached to foreign

bodies by a ligament. They have two long, fleshy arms, fringed with filaments, which they can protrude to a distance from their body, and retract in spiral coils at pleasure. The shell in which these curious arms are lodged, is lined with a vascular bilobed mantle, to which the functions of shell-secretion and respiration are assigned.

Among existing genera the ligament of attachment is long in *Lingula*, and permits the shell to float. *Orbicula* is sessile, and adheres by one end of a short muscle which perforates the valve. *Terebratula* is attached by a short pedicle which passes through a hole in the beak-like process of the valves, (fig. 162 and 163).

The body is so placed in the shell that the back corresponds to the centre of one valve, and the abdomen to the centre of the other. The shell is consequently equilateral, and its valves are called dorsal and ventral. Professor Owen says, that "in the terebratula the perforated valve must be regarded as the inferior or ventral one, and the imperforate or shorter valve the dorsal one." Professor Pictet holds a contrary opinion; he says, "the ventral valve is the smallest and generally supports in its interior, near to the hinge, the apophysal apparatus; the dorsal valve is the largest, and, in most genera, develops a beak-shaped process. The part which is bent against the ventral valve is called the *area;* the central part marked with lines of growth is the *deltidium*."

The form and structure of the area and deltidium afford good generic characters. The valves are frequently united by a bidentate hinge, the teeth of which so perfectly inter-lock in *terebratula*, that the valves are separated with difficulty. For this reason they are rarely found asunder in a fossil state.

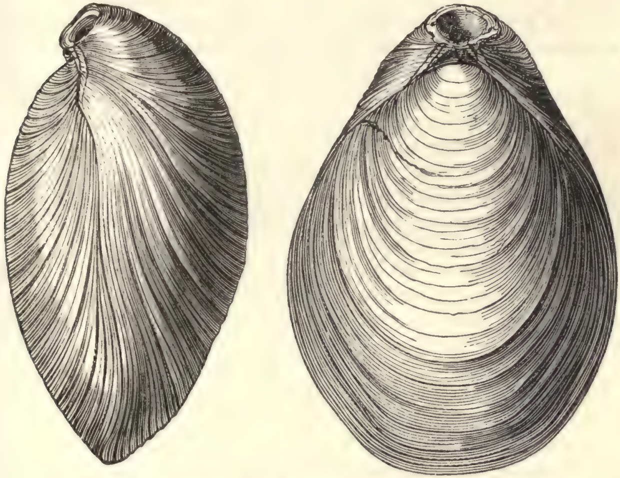
The palæontological history of this class is deeply interesting; it has been represented in the seas of all periods, and formed a fourth part of the molluscan population of the primary epoch.

In the secondary periods their numbers were relatively greatly diminished, and in the tertiary seas, the brachiopoda formed about one per cent. of the whole.

This class illustrates, in a satisfactory manner, the law of the speciality of fossils.

Thus, *calceola, chonetes, leptæna, productus*, are found only in the palæozoic rocks. *Spirifer* extends into the lias.

Atrypa, gypidium, and *pentamerus*, are ancient forms of terebratula, which lived only in the primary epoch, whilst the typical form of that genus flourished in the secondary periods to such an extent that entire beds are sometimes composed of its shells. A few species live in our modern seas.



FIGS. 162, 163.—Terebrátula with the valves in contact, from the coralline crag of Sudburn, Suffolk.

The CONCHIFERA are all enclosed in bivalved shells articulated together in a hinge-like manner. The animal is so placed in the shell that its back corresponds to the hinge, and the one valve covers the right, and the other the left side of the body; a position the reverse of that of the brachiopods, where one valve is dorsal and the other ventral.

The shell is lined with a vascular membrane called the mantle, which surrounds the body and secretes the shell. The animal is attached to its calcareous envelope by one or more muscles to close the valves and antagonise the elastic

ligament of the hinge, which constantly tends to open them asunder.

The animal has no head; the mouth is situated at the anterior part of the body and is surrounded by fleshy lips.

It opens into a short œsophagus which leads into a stomach and intestine of various lengths, and terminates in an anus. There is a large glandular liver for secreting bile, which is poured by numerous ducts into the digestive tube.

Circulation is accomplished by arteries and veins, aided by a symmetrical two-chambered heart; the ventricle of which in some genera surrounds a part of the intestine, the rectum.

Respiration is performed by four equal-sized branchial leaflets distinct from the mantle, and arranged symmetrically on each side of the body.

The nervous system consists of ganglia, situated at the anterior and posterior parts of the body, from whence nerves proceed to the labial organs, the adductor muscles, branchiæ, viscera, mantle, and foot.

In the *pecten* a number of bright little ocelli, or eyes, like small emeralds, are set round the free margin of the mantle. These organs of vision are found in several genera of the class,* as *arca, cardium,* &c.

The shell consists of the hardening material, the carbonate of lime, deposited in an organised gelatinous cellular membrane. The forms of the cells and structure thereof vary in the different families. The animal membrane and earthy matter are arranged in successive layers, the number of which increases with the growth of the mollusc, the largest and outermost being the last formed, as seen in *avicula longicostata* (fig. 164) from the lias.

The shell consists of external fibrous and internal nacreous layers. These two portions are often detached in fossil specimens. The internal nacreous lamina receives the imprint of the mantle, the insertion of the muscles, and forms the hinge for uniting the valves. The preservation of this layer is of great importance to the palæontologist, as the impressions made upon it by the organised parts of the body of the mollusc reveal the organisation of its ancient fabricator, with as

* Duvernoy du Système Nerveux des Mollusques.

much accuracy as do the forms and processes of fossil bones that of the vertebrate animals to which they belonged.

As our limits prevent us from giving a detailed description of the different parts of this calcareous envelope, we refer the student to the plate of the shells and description thereof, and to Sowerby's Illustrated Conchological Manual, for details on this part of the subject, and likewise for a description of recent and fossil genera.

In the grouping of this class the adductor muscles were regarded by Lamarck as affording a primary character; hence his division into *Monomyaria* and *Dimyaria*, according as they had one or two muscular imprints in each valve.

The foot is a muscular organ which most conchifera possess. It is employed for digging, leaping, and swimming, and other locomotive acts; and its form varies in the different genera. The following table of the families, by Deshayes, will assist the student to understand the value of the characters on which he has grouped this class:—

CONCHIFERA	DIMYARIA . .	The lobes of the mantle united in a greater or less degree, posteriorly	TUBICOLÆ.
			PHOLADARIÆ.
			OSTEODESMATA.
			MACTRACEÆ.
			TELLINIDES.
			CONCHÆ.
			CYCLADES.
			CARDIACEÆ.
			TRIDACNEÆ.
		The lobes of the mantle disunited . . .	NAYADES.
			TRIGONEÆ.
			ARCACEÆ.
			MYTILACEÆ.
	MONOMYARIA	Having a foot . .	MALLEACEÆ.
			PECTINIDES.
		Having no foot . .	OSTRACEÆ.

The shells of the conchifera are found in the most ancient rocks; their generic forms have slightly varied during the long periods of time which have elapsed between the primary epoch in which they commenced life, and the modern seas where they so greatly abound. Most of the genera which lived in the ancient periods exist at the present time, although the species has changed from one period to another.

Nothing is observed in the history of this class to justify

the supposition that there is any process of development from lower to higher forms.

We find some families prevailing at one period more than at another; for example, the *trigoneæ* in the oolitic. The *pernæ* and *grypheæ* in the neocomian rocks.

The most remarkable changes, however, have taken place in species at different periods. Thus Dr. Grant* has shown, in an analysis of Deshayes' labours on tertiary shells, that "nearly a thousand fossil species of *conchifera* have been obtained from the tertiary strata, and more than a seventh part of these are found to be identical with living species of the same or of distant latitudes. Seventy-two species of *ostrea* have been observed in tertiary strata of Europe, and of these, seven are identical with species now living in the ocean; of sixty tertiary fossil species of *pecten*, thirteen are identical with the living; of fifty-four tertiary species of *arca*, thirteen are also recent; of fifty tertiary *venericardiæ*, six are still living; of fifty-nine *cytheræ*, ten are recent; of fifty-nine *lucinæ*, nine are recent; of fifty-four *tellinæ*, twelve are recent; of thirty-five *corbulæ*, one is recent; of forty-three *veneres*, nine are recent; of thirty-nine *cardia*, seven are recent; of twenty-seven *pectunculi*, four are recent; of twenty-three *nuculæ*, four are recent; of twenty *chamæ*, four are recent; and of twenty-one tertiary species of *modiola*, three are found to be identical with the existing species.

"But in the same genera of bivalved mollusca the number of species found imbedded in the tertiary strata often exceeds that of the species now known in a living state: thus, twenty-three species of *nucula* are met with in the tertiary strata, and only seven species are now known in a living state; there are fifty known tertiary species of *venericardium*, and only twenty-five recent species; there are nineteen tertiary species of *astarte* and only three recent; fifty-nine tertiary *lucinæ*, and twenty living; thirty-five tertiary *corbulæ*, and ten recent; twenty-three tertiary *erycinæ*, and three recent; twenty-four tertiary *crassatellæ*, and nine recent. In many of the other genera of this class, the number of recent species much exceeds that of the species hitherto found in the tertiary strata; thus one

* Thomson's British Annual, 1832, p. 245.

hundred and one species of *venus* are at present known to inhabit our seas, and only forty-three species of this genus have been met with in the tertiary strata; of *cytheræa*, eighty-five recent species are known, and only fifty-nine tertiary species; of *cardium* fifty-three recent, and thirty-nine tertiary; of *mytilus*, forty-two recent, and fifteen tertiary; of *spondylus*, twenty-five recent, and nine tertiary; of *unio*, sixty-five recent, and only two tertiary; from the sub-apennine and the London basin fresh-water formations."

It appears, therefore, that there has been a constant oscillation in the numbers of species in each genus in the tertiary as compared with the modern epoch; but there has been no gradual perfectioning of the same.

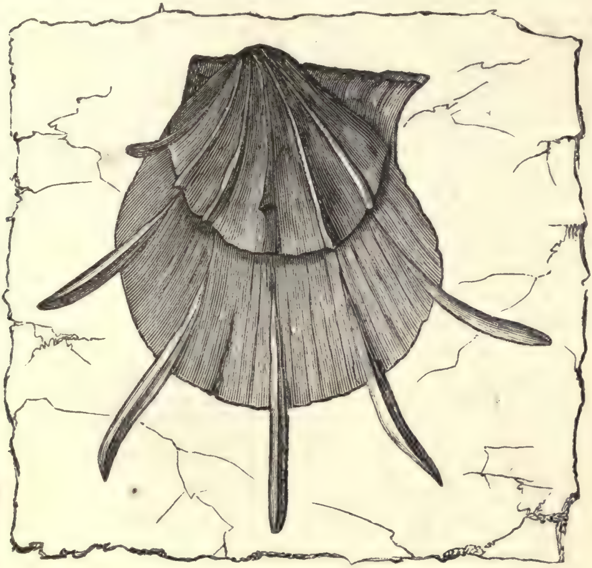


Fig. 164.—*Avicula longicostata*, Stutchb.

The Gasteropoda are characterised by the possession of a muscular disc or *foot*, placed along the under surface of the body, by which they slowly creep.

In one family this organ is modified into an oar for swimming.

The *head* supports from two to six tentacula placed above, but never around the mouth: sometimes they are absent, —they perform the function of touch, and probably those of smell and taste.

The *eyes* are small, and two in number; sometimes they are sessile on the head, sometimes they are placed at the base, at the sides, or at the extremities of the tentacula, and sometimes they are absent.

The *nervous system* consists of several ganglia dispersed through the body, and of a bilobed brain which occupies the upper surface of the œsophagus; and this tube is encircled by a nervous ring; from the ganglia, nerves proceed to the special organs of sense, the foot, branchiæ, digestive and generative organs.

The superior part of the body is covered with a fleshy *mantle*, which assumes a variety of forms. Some gasteropods are naked, and others have a shell concealed in the mantle; but the greatest number have for the most part a univalved shell, into which the animal can retire. As this organ is the only part of their bodies preserved in a fossil state, it is important that the student should make himself acquainted with its anatomy.

We subjoin, in an extended form, an explanation of fig. 165, and a description of the separate parts of the shells there depicted, commencing with the univalves.

a. Spire (fig. 1)
b. Body-whorl
c. Beak
d. Base
e. Canal
f. Aperture
g. Labrum, or outer lip
h. Labium, or columellar lip
i. Whorls, or Volutions
k. Sutures
l. Apex
m. Back (fig. 3)
n. Varices
o. Columella (fig. 4)
p. Septa (fig. 5)
q. Umbilicus (fig. 6)
r. Area, or anterior slope (fig. 7)
s. Areola, or posterior slope
t. Umbones (fig. 8)
u. Hinge
v. Ligament (fig. 2)
w. Disk (fig. 7)
x. Umbo
y. Base, or Ventral Margin
z. Height (fig. 9)
á Length
b′ Auricles
c′ Left valve (fig. 2)
d′ Right valve
é Valves (fig. 10)
f′ Lunule, or anal depression (fig. 2)
g′ Corselet, or escutcheon.

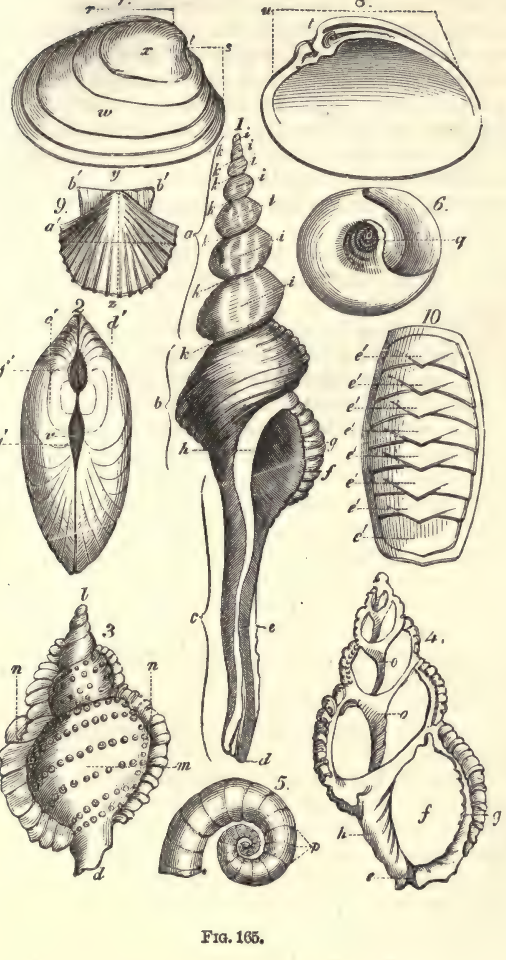


Fig. 165.

The spire, fig. 1, *a*, consists of all the whorls of the shell, except the last, which is called the body of the shell. The spire forms a very important feature in the univalves, and on its being raised, flattened, concealed, or reversed, depend many of the generic and specific distinctions of the shells.

The body-whorl, fig. 1, *b*, is the lowest; it forms the aperture, and is larger than the others.

The beak, or *rostrum*, fig. 1, *c*, is that lengthened process in which the canal is situate; it commences a little higher up, on the outside, than the insertion of the canal on the inside, which is always distinctly marked by the line of the aperture.

The base, figs. 1 and 3, *d*, in shells with a beak, is the extreme point; in those without a beak, it is the lowest part opposite the *apex*.

The canal, figs. 1 and 4, *e*, is the elongation of the aperture, in both lips of those shells which have a beak, in which it forms a channel, running from the aperture to the base.

The aperture or mouth, figs. 1 and 4, *f*, is the opening of the lower whorl, from which the animal protrudes; it constitutes one of the most important generic distinctions of univalve shells, and differs much, being in form circular, crescent-shaped, angular, linear, &c., &c. Some apertures have a canal at their base, others have none.

In some genera it extends the whole length of the shell, as in the *cypræa*, and some of the cones with depressed spires.

The *labrum*, or outer lip, figs. 1 and 4, *g*, is the expansion, or continuation of the body of the shell, on the right margin of the aperture, and is lined with the same pearly process as the aperture itself.

The *labium*, or columellar lip, figs. 1 and 4, *h*, is a continuation of the nacreous layer of the aperture, expanded on the columella.

The whorls, fig. 1, *i*, are the volutions of the shell, tapering gradually upwards, from the lower and largest, to the uppermost and smallest, at the summit.

The suture of the whorls, fig. 1, *k*, is a fine spiral line, which separates the volutions from each other. It is occasionally crenulated, undulated, sulcated, and sometimes raised or projecting.

The *apex*, fig. 3, *l*, is the highest point of the spire.

The back, fig. 3, *m*, is the side directly opposite to that in which the aperture is placed.

The *varices*, fig. 3, *n*, are ribs which cross the volutions in some species of *buccinum*, *murex*, and *triton*. They are formed by the periodical growth of the shells; the varices being the former margin of the outer lip, to which the animal has attached its successive enlargements.

The *columella*, or pillar, fig. 4, *o*, is that process which runs through the centre of the shell from the base to the apex, and is formed by the inner sides of the volutions of a spiral univalve. It constitutes an important feature in these shells; on the mode in which it is striated, grooved, folded, or otherwise marked, depend the generic and specific distinctions of many shells. It also forms the axis of revolution around which the volutions are turned. In consequence of the heart and great blood-vessels being usually placed on the left of the shell, the turns are commonly made from right to left; on the contrary, where the heart and blood-vessels are placed on the right side, the volutions are reversed, and proceed from left to right. In the first instance, the shell is termed *dextral;* in the latter, it is called *sinistral*, or *reversed*.

The *septa*, or chambers, fig. 5, *p*, are the cavities, divided by partitions, as in the nautilus, spirula, &c.

The *umbilicus*, fig. 6, *q*, is a circular perforation formed in the base of many univalve shells, when the inner side of the volutions do not join each other, so that the axis is hollow. Such is the case in the genus *trochus*, in some species of which it penetrates from the base to the apex. Those shells which have no *umbilicus* are termed *imperforate*.

BIVALVED SHELLS.—Fig. 2 represents a bivalve shell placed in its right position, which is that in which the animal is supposed to be walking along the bed of the sea, by means of its foot; the opening of the valves through which the foot protrudes is the *ventral margin*, and the opposite, the back, or *dorsal margin*. If the animal is walking forward, with its back to the observer, the *right* and the *left valves* will correspond with his right and left sides; in fig. 2 the shell is represented in this position; therefore *d* is the right valve and *c* the left.

The *area*, or posterior slope, fig. 7, *r*, is that part of the shell in which the ligament is placed.

The *areola*, or anterior slope, fig. 7, *s*, is the space opposite to that in which the ligament is placed.

The *umbones*, fig. 7 and 8, are the prominent points of the dorsal margin. They vary much in form, being proximate or remote, straight or bent, in the different families; in Pedunculus, they are *straight;* in Venus, *curved* towards the anterior margin; in Isocardia, *spiral;* in Chama, *decumbent;* in Diceras, *free.*

The hinge, fig. 8, *u*, is the point of the dorsal margin at which bivalve shells are united, either by the teeth of one valve inserting themselves between those of the opposite valve, or by a process of one fitting into a cavity of the other. The construction of the hinge, in conjunction with the general contour of the shell, affords generic characters for this class.

The ligament, fig. 2, *v*, is that flexible, cartilaginous substance by which the valves are united, and the shell opened, by means of its elasticity. It is always situated under the *umbones.*

The disk, fig. 7, *w*, is the convex centre of a valve, or its most prominent part.

The base, or ventral margin, fig. 7, *y*, is the part immediately opposite the *umbones.*

The height, fig. 9, *z*, is measured from the umbo to the ventral margin.

The length, fig. 9, *a'*, is calculated from the extreme edge of the anterior and posterior slopes, being in a contrary direction to the height.

The auricles, fig. 9, *b'*, *b'*, are the processes on each side of the *umbones.* Some species of *pectens* have one ear very large, and the other extremely small; while some are scarcely discernible on one side.

The valves of a multivalve shell are depicted in fig. 10, *e'*.

The *lunule*, fig. 2, *f'*, is the small depression on the dorsal margin, anterior to the umbones.

The *corselet*, or escutcheon, fig. 2, *g'*, is the larger depression posterior to the *umbones.*

There are a few other terms which may require explanation; thus the *muscular impression* is the mark made by the

insertion of the muscle into the valve. It is *single* or *double*, accordingly as the animal possesses one or two muscles; and varies in shape, being *circular*, *ovate*, *lunate*, *elongated*, &c. The *conchifera*, as they respectively possess one or two muscles, are termed *monomyaria* and *dimyaria.*

Striæ are fine thread-like lines on the external surface of shells. They are sometimes both longitudinal and transverse

If both valves are of the same size, the shell is said to be *equivalve.*

If one valve is larger than the other, it is said to be *inequivalve.*

If both sides are equal, it is termed *equilateral;* if one is larger than the other, it is called *inequilateral;* while the prefix *sub*, means nearly,—thus, *subequivalve*, signifies nearly equivalve, &c.

The Teeth.—The teeth constitute an important structure, since they serve for the definition of generic characters. They are *cardinal*, that is, placed in the centre; or *lateral*, that is, diverging from the *umbones;* they also vary extensively in shape and direction, being *incurved*, or bent round, *recurved*, or turned back, large or small, numerous, few, rounded, flattened, &c., &c.

The function of shell-secretion is performed by the glandular free margin of the mantle. Like the shells of conchifera, those of the *gasteropoda* are sometimes composed of several pieces, as in the *chitons*. (Fig. 10.)

The shells of the great majority of gasteropoda are rolled obliquely in consequence of the unequal development of the two sides of the body of the animal. They then form a helix, or an oblique spiral. Sometimes the coil is towards the right; at other times it is towards the left side: the direction of the spiral is in general constant in the species.

Some shells have a patelloid form, and are symmetrical without being spiral; and there are various intermediate forms by which these two extremes, the patelloid and spiral, are blended into each other. Some shells vary much in form at different periods of growth, as shown in the beautiful *cypræcássis rúfa* found by Mr. Stutchbury among the reefs of Paumotus, in the South Pacific,* (fig. 166), where

* Magazine of Natural History, vol. i., new series.

figure *a* shows the mature, and figure *b* the immature shell. This important fact should be recollected by the young naturalist. For further details on the anatomy of the shell, we refer to fig. 165, and the description thereof.

The mouth is surrounded by fleshy contractile lips, sometimes armed with teeth. We observe in some a singular file-like organ, which extends into the intestinal canal. It is formed of a ribbon-like membrane, which develops a series of tooth-like processes, the form and disposition of which

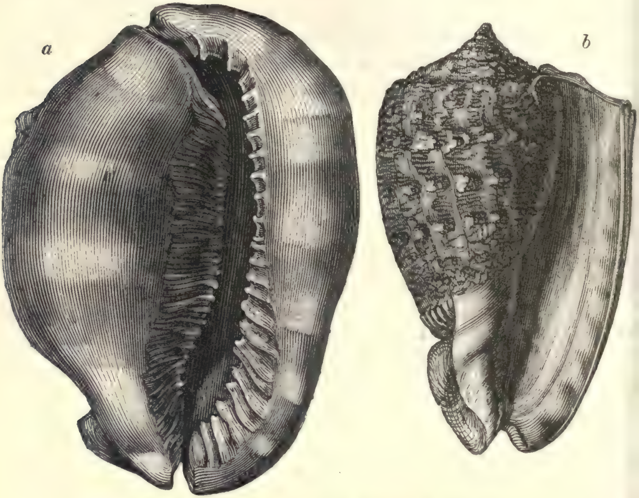


FIG. 166.—*Cypræcássis rùfa ;* *a*, mature ; *b*, immature.

vary in the different genera. These palates, as they are called, form beautiful microscopic objects, when neatly dissected out and mounted in Canada balsam. Those of *buccinum*, *nerita*, *patella*, *chiton*, and *doris* are interesting objects when viewed by *polarised* light.

The stomach is capacious, and is often armed with calcareous plates for dividing the food. The intestine is coiled upon itself, and lies between the lobes of the liver and ovary, and terminates in an anal aperture.

The heart is composed of an auricle and ventricle. Its position, with that of the respiratory tube, is always on the side opposite to that towards which the shell is coiled.

As the genera of this class are terrestrial, lacustrine, and marine, the organs of respiration are modified in accordance with the habitat of the animal.

The terrestrial and some lacustrine species breathe by a lung, situated at the anterior and superior part of the body, which opens and shuts, at the will of the animal, by the action of a muscular sphincter.

On the walls of this air-sac a beautiful net-work of pulmonary vessels ramify, whereby the blood is aërated. The species organised for an aquatic life possess branchiæ, the form, structure, and arrangement of which vary much in this class. So permanent are the characters afforded by these organs, that they form the basis of their methodical distribution into orders, as shown in the following table:—

THE GASTEROPODA.

Having a Lung				PULMONALIA.
Having the Branchiæ	concealed	in a dorsal cavity, opening above the head. The shell	Turbinated .	PECTENIBRANCHIATA.
			Tubiform .	TUBULIBRANCHIATA.
			Shield-shaped	SCUTIBRANCHIATA.
		under a fold of the dorsal mantle, which contains almost always a shell.		TECTIBRANCHIATA.
	Naked and disposed	under the free border of the mantle . .	with a shell composed of one or many pieces .	CYCLOBRANCHIATA
			without a shell . .	INFEROBRANCHIATA.
		In symmetrical tufts on the back		NUDIBRANCHIATA.

The gasteropoda are found in the rocks of the Silurian and of all subsequent periods; their numbers gradually augment, and their forms become more and more varied in the secondary and tertiary strata; but their greatest development was reserved for the seas of the modern epoch.

The remains of this class are highly important to the geologist, as they afford him unequivocal evidence of the fluviatile, lacustrine, and marine conditions under which

strata were formed. We are indebted to Professor Grant* for the following summary of this class:—

The species of gasteropods are much less abundant in the ancient grauwacke limestones than those of bivalved mollusca; only about seventy species of the former having been yet identified in the strata of that epoch, and a quarter of these belong to the extinct genus *euomphalus*, which ceases with the carboniferous rocks. Most of the species, however, observed in these ancient grauwacke formations are referred to existing genera, as *turritella*, of which about ten species occur; *turbo*, six species; *buccinum*, *patella*, *delphinula*, five each; *nerita*, *pileopsis*, *trochus*, and *phasianella*, three species each. The gasteropodous genera continue in nearly the same proportions in the carboniferous strata, and several even of the species are identical in the two formations; as, *pileopsis vetusta*, *melania constricta*, *euomphalus nodosus* and *citillus*, *turbo tiara*, *rotella helicinæformis*, *buccinum acutum*, and *turritella prisca*. The *euomphalus*, *turritella*, *trochus*, *turbo*, and *nerita* are still the most abundant genera of the carboniferous gasteropods; and a few species only of this class have been recognised in the coal measures, or in the new red sandstone group of rocks; but in the oolites more than a hundred and thirty species of univalves occur, which belong chiefly to the genera *trochus*, *patella*, *turbo*, *nerinæa*, *turritella*, *actæon*, *melania*, *natica*, *cirrus*, *pleurotomaria*, *nerita*, *cerithium*, *rostellaria*, *pterocera*, and *trochotoma*.

In the cretaceous rocks, not half of the number of gasteropods occur which are found in the oolitic formations, and they belong, for the most part, to the recent genera, *trochus*, *rostellaria*, *turbo*, *cirrus*, *vermetus*, *auricula*, and *dentalium*. But so abundant are these animals in the marine deposits of the tertiary epoch, that more fossil species belonging to a single genus are found in them than belong to all the cretaceous genera of gasteropods taken collectively; thus, two hundred and twenty fossil species of *cerithium* are met with in the tertiary strata—a number nearly treble that of the known existing species of that genus; one hundred and fifty-six species of *pleurotoma* are found in the tertiary formations; one hundred and eleven species of *fusus*, and ninety-five

* Thomson's Annual, p. 247.

of *buccinum*. A few only of the tertiary genera are now entirely unknown in a recent state; as, *pileolus*, *omalaxon*, and *pleurotomaria;* and some entire genera of this class, at present inhabiting the waters of the globe, have not yet been met with in any of the tertiary strata, as *rotella*, *magilus*, *stomatia*, *navicella*, *scarabæus*, *succinea*, *anostoma*, *vitrina*, *testacella*, and *dolabella*.

Many genera of gasteropods, most abundant in existing species, present comparatively few fossil species in the tertiary formations: thus, three hundred and twenty-five living species of *helix* are at present known, and only thirty-five species of that terrestrial pulmonated genus have been observed in the tertiary strata. Although one hundred and four living species of *patella* are known to inhabit the ocean, only ten fossil species have been recognised in the tertiary marine formations; of *neritina*, there are sixty known recent species, and only seventeen tertiary fossil species; of *haliotis*, twenty-nine recent, and one tertiary fossil; *trochus*, one hundred and three recent, and seventy tertiary fossil; *monodonta*, forty-two recent, and eight fossil; *strombus*, forty-five recent, and nine fossil; *buccinum*, one hundred and forty-three recent, and ninety-five tertiary; *mitra*, one hundred and twelve recent, and sixty-six tertiary; *cypræa*, one hundred and thirty-five recent, and nineteen tertiary; *conus*, one hundred and eighty-one recent, and forty-nine tertiary fossil species, and only one of all these species of *coni* is found to be common to the tertiary and the recent epochs. In most of the genera of gasteropods, however, as in other classes of animals, there are several species which have survived the tertiary deposits, and still continue to exist in a living state. Seven species of *cypræa* are found common to the tertiary formations and our present seas; twenty species of *buccinum* are both tertiary and recent; six species of *cassis*, six of *triton*, fifteen of *murex*, eleven of *fusus*, seven of *cerithium*, twelve of *trochus*, nine of *natica*, and the same number of tertiary species of *helix*, are found still living on the continent of Europe.

The PTEROPODA swim by musculo-membranous expansions of the mantle, which project from the sides of the head. Their body is naked, or is partly protected by a delicate shell. They are small animals that float on the surface of

the ocean at a great distance from any shore. In the North Seas the *clio* and *limacina* swarm in such abundance that they are said to constitute the food of the great whale. The *clio* is provided with a singularly complex apparatus, which escaped the keen eye of Cuvier, but has recently been described by Professor Eschricht of Copenhagen. The head is furnished with six retractile appendages, which have a reddish tint, from the number of distinct red spots distributed over their surface, amounting in each to about 3000. When viewed with the microscope, each speck is seen to be the orifice of a sheath which contains about twenty pedunculated sucking discs, that are capable of protrusion for the prehension of prey; so that the head of *clio borealis* is armed with $3000 \times 20 \times 6 = 360,000$ microscopic pedunculated suckers; an instrument which for complexity is quite unique in the animal series. *Clio* and *pneumodermon* are naked gasteropods, but *hyalæa, cleodora,* and *cymbulia* possess shells of extreme delicacy.

From the absence in some, and the fragility of the skeletons of others, of this class, we rarely find their remains in a fossil state.

The tertiary beds of Dax and Turin contain two extinct species of *hyalæa*. The Miocene beds of Bordeaux, the sub-apennine beds of Piedmont, and the English crag, contain several species of *cleodora*.

The *conularia* of the palæozoic rocks is now considered an extinct genus of this class.

The CEPHALOPODA have a thick, soft, fleshy body, of a spherical or elliptical form, sometimes protected by a shell, sometimes naked. The mantle is a musculo-membranous sheath, which encloses the digestive, respiratory, circulating, and generative organs. The head is distinct from the trunk; is of a large size, and round form. It contains the organs of the five senses, and those for mastication and deglutition. It is surrounded by a circle of fleshy processes, or feet, from whence the name of the class, "head-footed," is derived. The eyes are two in number, of large size, and highly organised; and are either sessile or pedunculate. The mouth is armed with a pair of vertical, horny, or calcareous jaws, which resemble the bill of a parrot, and enclose a fleshy tongue, the mucous covering of which develops a series of recurved horny spines.

Respiration is performed by symmetrical branchiæ lodged in a fold of the mantle: in the first order, there are two; in the second, four of these organs. There is a fleshy ventricle for the circulation of the blood through the body, and like organs to aid its passage through the gills. The funnel is a membranous tube, situated at the under side of the neck; it gives passage to the water for respiration, and exit to the effete matters that are discharged from the body. The class is divided into two orders:—

The TENTACULIFERA, D'Orb., (*Tetrabranchiata*, Owen,) of which the Nautilus Pompilius is the type, have large external univalve shells, symmetrical in form, and divided internally by septæ into a series of chambers, the last formed being very capacious, for lodging the body of the animal. A tube, or siphon, passes through all the chambers, without communicating with them, and opens into a muscular sac that surrounds the heart.

This apparatus appears to be destined to facilitate the ascent and descent of the animal in the water, by determining an increase or diminution in the specific gravity of the shell, as the pericardial sac communicates with the sea by two openings; the reservoir and siphon can be distended with water, thereby augmenting the specific gravity of the shell, and causing it to sink; or emptied by the contraction of its muscular walls, thus enabling it to float.

The weight of sea-water, which the siphuncular apparatus contains, is the ballast by which the tentaculifera ascend or descend in the water.* The body is attached to the last chamber of the shell by two lateral muscles; the head is surrounded by numerous hollow tentacula, and they have a muscular disc for creeping. Their eyes are more simple in structure than in the acetabulifera, and are pedunculated.

They have no organ of hearing; the jaws are strengthened by a calcareous coating; they have four gills, but no ink-bag. As the shells of all the tentaculifera (the pearly nautilus excepted) are extinct, the study of these organisms is of great importance to the geologist. We divide this order into three

* Dr. Wright, Philosophical Magazine, vol. xii. p. 503.

families, according as the siphon is in the centre, or nearly in the centre, of the septum, or on the internal or external border of the shell.

The position of the siphon must, therefore, be accurately determined in the study of fossil species.

1st Family.—The NAUTILIDÆ.—Siphon placed in the middle, or almost in the middle, of the septa; shell spiral or straight; septa, simple or sinuous; never ramified, nor angular at the borders; provided with an opening, generally sinuous, at the internal dorsal border.

This Family contains only one existing genus, the *nautilus.* Shell spiral; rolled on the same plane; volutions at all ages contiguous, apparent or concealed. This genus contains more than 112 fossil species, of which the first are of the Devonian stage. It had its maximum of specific development during the carboniferous stage. After having traversed all the subsequent periods, we find only two species in the warm seas of the present day. They are the only representatives of the once numerous and varied genera of tentaculifera.

The NAUTILI, are almost always, during their embryonic age, provided with striæ, although they may be smooth in later life. The species, with the *volutions exposed*, in general belong to the palæozoic strata. The species *striated* longitudinally are generally oolitic, and the *radiated* species are cretaceous. (Fig. 167.)

The *lituites*, *hortolus*, *nautiloceras*, *aploceras*, *gomphoceras*, *gonioceras*, *orthoceratites*, *actinoceras*, and *andoceras*, are special to the palæozoic rocks.

The *orthoceratites* range through the palæozoic, and extend to the triasic strata.* The *nautiloceras* commenced in the carboniferous, and became extinct at the close of the triasic period, whilst the true *nautilus* commenced in the Devonian, is found in every subsequent stage, and lives in our present seas.

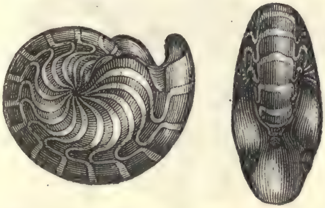
2nd Family.—CLYMENIDÆ, D'Orb.—Siphon placed at the internal part of the septa; shell spiral, arched, or straight; septa more or less angular at the borders. The genera of this family, as *melia*, *cameroceras*, *phragmoceras*, *clymenia*, are extinct, and special to the palæozoic rocks. *Megasiphonia* is

* Pict. Atlas, Pl. lix.

found in the tertiary strata. We give a figure (168 and 169) of *Megasiphonia zic-zac*, from the London clay of Primrose Hill.

FIG 167.—Nautilus Elegans.—Chalk.

3rd Family.—AMMONITIDÆ.—Siphon placed at the external dorsal part of the septa; shell spiral or straight, arched or bent in various forms. The aperture generally prominent at the external dorsal margin; septa almost always angular, or ramified at the borders divided into lobes and saddles.



FIGS. 168 and 169.—Megasiphonia zic-zac.

The genera *oncoceras*, *cyrtoceras*, *gyoceras*, *cryptoceras*, *stenoceras*, are found in the palæozoic strata. *Goniatites* are Devonian and carboniferous, and *ceratites* are triasic forms.

G. AMMONITES.*—Shell forms a regular spiral, rolled on the same plane, with the turns contiguous. (Figs. 170, 171, 172.)

D'Orbigny, after making due allowance for varieties

* Pict. Atlas, Pl. lx. and lxi.

occasioned by age, sex, and diseased conditions, has identified 530 species of this genus. They are represented by numerous species in the triasic, and are very abundant in all the stages of the oolitic and cretaceous periods. In each of the eighteen geological stages in which ammonites are found, certain groups of specific forms, distinguished by Von Buch by appropriate names, are found to characterise certain beds; thus, the groups known as *arietes* and *falcifera* are special to the lias. *Amalthei*, *ornati*, *capricorni*, are oolitic. *Flexuosi* is neocomian; *cristati*, *tuberculati*, *clypeiformi*, *pulchelli*, *rhotomagenses*, and *dentati*, are cretaceous.

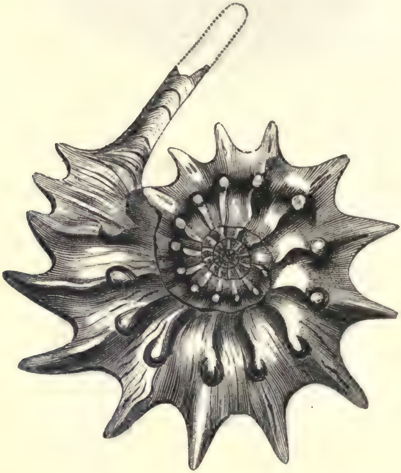


FIG. 170.—Ammonites Jason.—Oxford clay.

The *ancyloceras* (fig. 173) and *helicoceras* commenced their existence in the seas of the great oolite, and extended into the upper stages of the chalk. The *scaphites*, *baculites*, *hamites*, *turrilites*, *crioceras*, *ptychoceras*, and *heteroceras*, are generic forms special to the cretaceous period.

The ACETABULIFERA, D'Orb., (*Dibranchiata*, Owen,) form the most highly organised group of this class. The arms are provided with acetabula, or sucking discs, for adhe-

sion to bodies. In one genus, *octopoda*, which has not been found in a fossil state, there are eight. In all the other

FIG. 171.—Ammonites Varians.—Chalk.

FIG. 172.—Ammonites Mantelli.—Chalk.

genera there are ten of these acetabuliferous arms. The *shell*, when it exists, is rarely external, and is mostly internal. We only know one genus, the *argonauta* (paper sailor), which is protected by an external univalve shell. There is no siphuncular apparatus, nor is the body of the animal attached to it by muscles. We know a fossil species, *A. hians*, from the sub-apennine of Piedmont. When the shell is internal, it is horny, or testaceous, and is sometimes provided with air-chambers and a siphon; but the last

chamber is incapable of receiving the body of the animal, as is the case in the polythalamous shells of the tentaculifera.

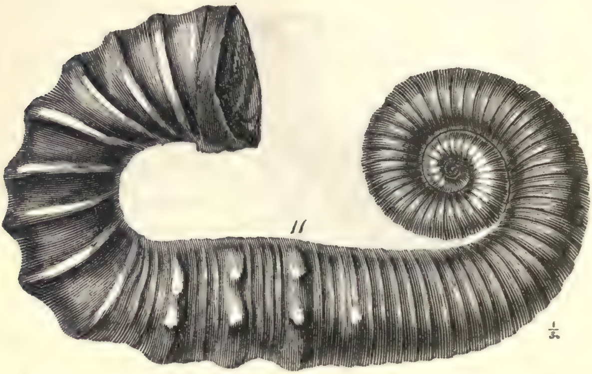


FIG. 173.—Ancyloceras gigas. (Lower greensand).*

The ten-armed cephalopods, called *decapoda*, with internal shells, form several families.

The SPIRULIDÆ have an internal calcareous shell, formed of a series of air-chambers, traversed by a siphon. It contains living and fossil genera, as *beloptera, spirulirostra,* from the tertiary stages of France.

The LOLIGIDÆ are provided with an internal horny plate of a feather-like form, without air-chambers; several fossil genera are found in the oolitic rocks.

The TEUTHIDÆ have an internal plate or blade, much elongated, like an arrow, without air-chambers. It contains three fossil genera which belong to the Oxfordian stage of the oolitic period.

The BELEMNITIDÆ have an internal horny skeleton and a testaceous shell, formed of air-chambers piled on each other in a straight line, and traversed by a lateral and marginal siphon. All the genera of this family are extinct. They are distributed throughout the rocks of the oolitic and

* We have a noble specimen of this fossil in our cabinet, from the Isle of Wight, which measures eighteen inches in length and twelve inches in depth.

cretaceous periods, and characterise the beds by their specific forms.

In taking a general review of this class, we observe the TENTACULIFERA among the first animal forms of our globe. They attained their greatest development in the seas of the Silurian period. We count twenty-two genera in the palæozoic rocks; seven in the triasic; and the same number in the oolitic; fourteen in the cretaceous period; and only two in the tertiary strata. Of this once extensive group, a single genus lives in our modern seas.

The ACETABULIFERA commenced in the muschelkalk; in the oölitic rocks are twelve genera; and in the cretaceous and tertiary strata, there are four. Of all these genera five only now survive. Comparative calculations on this order must be made with much caution, as their rudimentary internal skeletons do not afford such positive data as the external shells of the tentaculifera.

Of the *tentaculifera* one conclusion may be drawn from the physiology of this class. The *nautilus* now only inhabits the Indian ocean, whilst extinct species of this genus of large size are found in the tertiary strata of our island, and in beds of the same age in France and Belgium; thus affording evidence that the European seas of the tertiary epoch had a much higher temperature than they now possess.

The following Table, by Alcide D'Orbigny,* exhibits a stratigraphical distribution of the Eighteen Thousand Species of Mollusca and Radiata, which served as the basis of his generalisations on the speciality of Fossil Animals. It enables the student to form a correct idea of the numerical value of the species which characterise each stage and period into which the fossiliferous rocks are divided.

PERIODS.	Stages	= Formations.	*Number by Stages* of the Species of Mollusca.	*Number by Stages* of the Species of Radiata.	Total Species *in each Stage.*	Total Species *in each Period.*
Tertiary	27 Sub-apennine	= Pliocene	444	162	606	6040
	26 Falunian	= Miocene	2903	160	3063	
	25 Parisian	= Eocene...............	1478	199	1677	
	24 Suessonian	= Nummulite rock	562	132	694	
Cretaceous	23 Danian	= Upper chalk	47	17	64	4098
	22 Senonian		1061	507	1568	
	21 Turonian	= Lower chalk	218	148	366	
	20 Cenomanian	= Upper greensand	627	183	810	
	19 Albian	= Gault	307	52	359	
	18 Aptian	= Lower greensand and Wealden...	146	4	150	
	17 Neocomian		656	124	781	
Oolitic	16 Portlandian	= Portland beds ...	59	2	61	3785
	15 Kimmeridgian	= Kimmeridge clay	184	16	200	
	14 Corallian	= Coral rag	403	235	638	
	13 Oxfordian	= Oxford clay	499	230	729	
	12 Callovian	= Kelloway rock ...	253	25	278	
	11 Bathonian	= Bath oolite.........	407	125	532	
	10 Bajocian	= Inferior oolite......	508	94	602	
	9 Toarcian	= Upper Lias.........	273	14	287	
	8 Liasian	= Middle Lias	270	13	283	
	7 Sinémurian	= Lower Lias.........	163	12	175	
Triasic	6 Saliferian	= Red marls	619	114	733	840
	5 Conchylian	= Muschel-kalk ...	104	3	107	
Palæozoic	4 Permian	= Magnesian Limestone	82	9	91	3184
	3 Carboniferian	= Carboniferous	887	161	1048	
	2 Devonian	= Devonian	1054	146	1200	
	1 Silurian	= B. Superior, or Murchinsonian	356	61	418	
		A. Inferior, or Silurian	375	52	427	
		General total..................	14,947	3,000	17,947	17,947

* Cours de Paléontologie, p. 260. The English equivalents of D'Orbigny's stages have been introduced to assist the student.

THIRD DIVISION.

ARTICULATA, *Cuvier*. DIPLO-GANGLIATA, *Grant*.

The articulated animals afford a wide field for the investigations of the zoologist and comparative anatomist; but their palæontological history is much behind that of the other divisions of the animal kingdom.

The Articulata have a body composed of a series of rings, which give the animal an articulated or jointed appearance. The skin is often indurated by a deposit of the carbonate and phosphate of lime, as in the crustacea, or by a peculiar horny substance called chitine in insects. The rings of the body support lateral appendages, which are metamorphosed into various organs in different parts of the same: thus the appendages of the rings of the head form the antennæ, jaws, and other parts of the mouth in insects, spiders, and crustacea: those of the thorax form the feet in crustacea and spiders, and the wings and feet in insects.

The nervous system is composed of a chain of ganglia disposed in pairs, and united by nervous cords: hence the term diplo-gangliata. The first pair of ganglia forms the brain, which reposes on the upper part of the œsophagus. A nervous thread descends on each side of that tube, to unite the brain with the second pair of ganglia which lie below it; and thus the œsophagus is surrounded by a nervous collar. In the larval condition of insects the nervous system may be conveniently studied. Each ring of the body is seen to have its own ganglionic centre, from whence nerves proceed to the various organs contained therein. The nervous system undergoes important changes during the development of the animal. In the larva, it is worm-like, with ganglia corresponding to each ring. In the perfect insect, several ganglia coalesce to form two or more nervous centres, from whence lashes of filaments are given off. As an equal distribution of the ganglia is one of the characters of the larva state, a union or fusion of the ganglia into masses indicates a higher grade of organisation. In this division, all the *Worm-like*

classes have a nervous system, with numerous ganglia: all the *Entomoid classes* have the ganglia fused into two or more centres.

The eyes are either simple or compound. In *annelida* and *spiders* they are simple; in *insects* and *crustacea* they are compound. This division comprehends Six Classes:

ANNELIDA.	ARACHNIDA.
CIRRHIPODA.	MYRIAPODA.
CRUSTACEA.	INSECTA.

CLASS I.—ANNELIDA.

Have an elongated vermiform body, divided into numerous rings. They are for the most part naked, or are enclosed in tubes; sometimes membranous, and indurated with grains of sand or other débris; or calcareous, and adhering to shells and other marine bodies. These tubes are almost the only remains of the Annelida that lived in the ancient seas; although the foot-prints of some naked forms are impressed on the ancient sedimentary strata. We divide this class into two orders.

The ANNELIDA DORSIBRANCHIATA.—Have a naked body, composed of numerous rings; the lower arc of each ring carries bristles for locomotion, and the superior arcs of many support the branchiæ for respiration. To this order belong the remarkable imprints of *Nerites Cambrienses*, impressed on the Lampeter Cambrian rocks.

The ANNELIDA TUBICOLA.—Have the body enclosed in membranous or calcareous tubes, generallyadherent to shells or other marine bodies. These tubular sheaths are the only remains we possess of this order. The genus *Serpula* extends from the Devonian stage to the modern epoch: it attained its greatest development in the oolitic seas. More than fifty species are found in the rocks of this period. *Terebella* is found in the oolites, *Spirorbis* in the chalk and tertiaries, and *Siliquaria* in the tertiary strata of France and Italy.

Class II.—CIRRHIPODA.

This class was for a long time considered to belong to the Mollusca; but the structure of the nervous system, and the physiological facts which have been ascertained relative to the mode of their development, prove that the cirrhipedes belong to the Articulata. They are marine animals, attached in the adult state either by a peduncle or by a shell to submarine bodies. The appendages are in the form of jointed cirrhi, and the body is enclosed in a multivalve calcareous shell. In recent genera the valves are either united or separated by membranes. In the fossil forms, the valves of the shell are generally detached. The class comprises two families: the pedunculated, or Anatifidæ, and the sessile, or Balanidæ.

The Anatifidæ have a multivalve shell, attached by a fleshy peduncle; the valves are united by a membrane. A fossil species of the genus *Anatifa* is found in the miocene stage of the tertiaries of France. *Pollicipes* occurs in the Stonesfield slate of England, and in the cretaceous and tertiary rocks. *Aptychus*, which was considered by some to be a tooth, by others to be the operculum of an ammonite, is now described by D'Orbigny as an extinct genus of this family nearly allied to anatifa. This singular form lived in the palæozoic, but attained its greatest development in the oolitic period: it is likewise met with in the chalk.

The Balanidæ have a complicated, many-valved shell, attached to sub-marine bodies; the aperture through which the cirrhi project is closed by an opercular apparatus, composed of several pieces. We find fossil species of *Balanus*, *Acastra*, *Coronula*, and other existing genera, in the tertiary strata.

Class III.—CRUSTACEA.

This class comprehends all the articulated animals with articulated feet, which have a heart for circulation, and branchiæ for respiration. The crabs and lobsters are the true types of the class; but it comprehends a great many orders, which differ widely from these. The skeleton is in the form of an external crust, or shell, partaking of the character

of an epidermis, exuded from the vessels of the skin, and hardened with a considerable proportion of the carbonate and phosphate of lime. At certain periods this crust is thrown off, to permit of the growth of the animal.

The skeletons of this class are preserved in the rocks of all epochs, and certain generic forms are special to the stages of different periods, which they serve to characterise. This law will be better understood after taking a rapid glance of the orders.

Order XIPHOSURA, or King Crabs.—Have the body covered with a large cephalo-thoracic shield; the abdomen is very small, and terminated with a long styliform tail; the jaws, or organs of the mouth, resemble those for locomotion. Mastication is performed by one of the joints of the jaw-feet, which has a cutting border for that purpose. They have two large compound, and two small simple eyes, situated on the anterior and lateral parts of the thoracic shield.

Limulus is found in the carboniferous stage of the palæozoic rocks, in the Oxford stage of the oolitic, and lives in our present seas. *Halycina* belongs to the muschelkalk, and *Bellenurus* is limited to the palæozoic strata.

Order CYPROIDA.—Have the body enclosed in a bivalve shell, united by a hinge along the back. The animal can

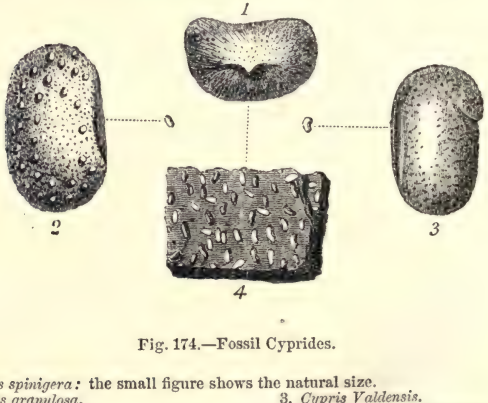


Fig. 174.—Fossil Cyprides.

1. *Cypris spinigera:* the small figure shows the natural size.
2. *Cypris granulosa.* 3. *Cypris Valdensis.*
4. Clay, with numerous cases of the species represented; *fig.* 1, of the natural size.

close the valves entirely, and protrude the feet and antennæ at pleasure. They are microscopic beings, and abound in the sea and in fresh water. We know five fossil genera, of which two, *Cypridella* and *Cyprella*, are special to the carboniferous stage. *Cytherina* is found in the Silurian rocks, *Cypridina* commenced in the carboniferous, and *Cypris* in the wealden stage. We find species of these three latter genera in our present seas, lakes, and marshes. The remains of *Cypris*, a lacustrine genus, are so abundant in the wealden of Kent and of the Isle of Wight, that some of the clays of this stage have a foliated character, each lamina thereof being entirely covered with their bivalve shells. The accompanying figures represent three species common in the wealden of Sandown and Brook Bays, Isle of Wight (fig. 174).

Order TRILOBITES (or *Paleades*, Dalman)—Had the carapace composed of several rings, divided into three lobes by two lateral depressions. It is not easy to decide at what ring the thorax terminates and the abdomen commences. Burmeister thought that we ought to name all the free segments up to the last cephalo-thoracic, and those concealed under the latter abdominal rings. The number of the thoracic segments varies from five to twenty; they present many intermediate numbers in the different families.

The lateral lobes of the anterior or cephalic segment support the eyes, which are prominent, kidney-shaped, and compound, and are often preserved in a high state of perfection (fig. 175).

The mouth is imperfectly known, and we have not found

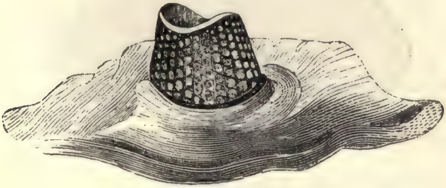


FIG. 175.—The compound Eye of a Trilobite.

antennæ. The feet were membranous. We know only one, *Calymene*, from America, where these appendages are preserved. Many trilobites had the power of rolling themselves into a ball, from which we conclude that the abdomen had no special appendages at its extremity.

The tegumentary skeleton of this order is formed in general of two distinct layers: the external is thin, often granulated, and ornamented; the internal, which is always present, is denser than the former. The Trilobites all belong to the palæozoic rocks. They lived in numerous families, and presented an immense association of individuals, but were much restricted as regards the number of the genera and species.

Burmeister distributes the Trilobites into six families.

The Asaphidæ had the power of rolling the body into a ball: their dorsal axis is not contracted posteriorly; the carapace is often sculptured with lines, but is seldom granulated. Most of the genera have less than ten rings to the thorax. It comprises *Illænus*, *Bumaster*, *Archegonus*, *Dysplanus*, *Amphyx*, and *Asaphus*. These genera range between the lower Silurian and the carboniferous stages.

The Calymenidæ had the power of rolling themselves into a ball; the dorsal axis of the body is contracted posteriorly; the carapace is often granulated, and they had for the most part more than ten rings in the thoracic division of the body. It comprehends *Calymene*, *Cyphaspis*, *Phacops*, *Æonia*, and *Homalonotus* (fig. 176). This family ranged through the Silurian, Devonian, and carboniferous periods.

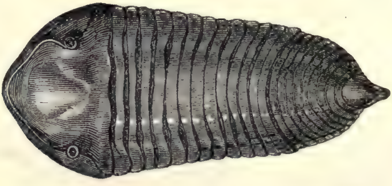


Fig. 176.—Homalonotus delphinocephalus. König.

The Harpesidæ. The lateral lobes of the body-rings are

not extended horizontally in their whole length, but turned downwards from the centre, and do not terminate in a point, but with an arched and rounded extremity, furrowed on the surface along their whole length. The genera *Conocephalus*, *Ellipsocephalus*, and *Harpes* belong to this tribe; they are confined to the upper Silurian and Devonian stages.

The OLENIDÆ were incapable of rolling themselves into a ball; the caudal shield is very small, the axis of which is many-jointed, but always shorter than the body: it includes the genera *Paradoxides* and *Olenus*, which are limited to the upper and lower Silurian stages.

The ODONTOPLEURIDÆ have the form of the *Ogygidæ*: like them they were incapable of assuming the globular form. The abdominal shield is smaller than the thoracic, and consists of few segments. It includes *Odontopleura*, *Arges*, and *Brontes* of the upper Silurian and Devonian stages.

The OGYGIDÆ were incapable of rolling themselves into a ball; the lateral lobes of the rings of the body are situated on the same plane, and do not curve or bend downwards, but terminate posteriorly in a point or spine more or less prominent, sometimes very long, which forms an obtuse angle with the direction of the lobes. The abdominal shield is simple, almost as large as the cephalic, and as long as the thoracic, and is composed of many separate elements. In this family is grouped *Trinucleus*, and *Ogygia*, which are found in the Silurian stages.

The EURYPTERIDÆ, it is supposed, had no shell. We only know the existence of the family by the impression of the body and head, with antennæ, and compound eyes of *Eurypterus*, in the inferior stage of the Silurian rocks of North America.

Order PHYLLOPODA.—Are naked or covered with a bivalve carapace. Their body is divided into numerous segments, which support foliaceous branchiferous feet. Belonging to this order is *Nebalia* and *Apus*, from the carboniferous stage.

Order ISOPODA, of which the common wood-louse, *Oniscus*, is typical.—Have the thorax composed of seven segments

nearly equal in size, each supporting a pair of feet; and the same number of rings in the abdomen. It comprises the ONISCIDÆ, which are terrestrial. Some species are found fossil in amber, from the superior tertiary beds.

The SPHÆROMIDÆ contains all the marine forms allied to the preceding. The fossil genera are considered to differ from those living in our own seas. From the Oxford stage of the oolites of Bavaria, Count Münster has obtained *Alvis*, *Urda*, *Norna*, *Sculda*, *Reckur*, and *Naranda*. *Archæoniscus* is found in the wealden of England and France, and *Palæoniscus* in the tertiary beds of Paris.

Order AMPHIPODA.—Have sessile eyes; the branchiæ are attached to the seven thoracic feet; the abdomen is composed of seven segments, of which the four last are modified to form an organ for leaping or swimming. Belonging to this order is the genus *Typhis*, from the older tertiary strata of America.

Order STOMAPODA.—Have the eyes pedunculated and moveable. To this group the *Squillidæ* belong. The impression of a fossil species of *Squilla* has been found in the tertiary beds of Monte-Bolca.

Order DECAPODA.—Have the head and thorax covered by a hard shield, the eyes pedunculated and moveable, the branchiæ enclosed in the thorax; they have five pair of thoracic feet, of which the anterior pair are formed into powerful forceps. There are six pairs of mouth-organs or jaws. It comprehends the following families.

The PALŒMONIDÆ, or Prawns, contain a great many existing genera. Count Münster has described, from the Oxford stage of the Bavarian oolites, the following fossil genera:—*Œger*, *Antrimpos*, *Bylgia*, *Drobna*, *Kælga*, *Udora*, *Dusa*, *Hefriga*, *Bombur*, *Blaculia*, *Elder*, *Rauna*, *Saga*. To these may be added a fossil species of *Crangon* from the upper lias of Normandy.

The ASTACIDÆ, or Lobsters, form an extensive family in our modern seas. The fossil genera, which are numerous in the oolites, may be separated thus: *Coleia* is found in the liasic stage. *Glyphœa* in the inferior oolite. *Magila*, *Orphnea*, *Brisa*, *Brome*, *Bolina*, *Aura*, *Pterochirus*, *Klytea*, *Eryma*, *Megachirus*, are chiefly from the Oxford stage of Bavaria.

To this family belongs the beautiful *Astacus*, from the neocomian stage of Atherfield, Isle of Wight * (fig. 177).

FIG. 177.—Astacus Vectensis.

The PALINURIDÆ, PAGURIDÆ, DROMIDÆ, LEUCOSIDÆ, and GRAPSIDÆ, have fossil genera in the oolitic, cretaceous, and tertiary strata.

The CANCERIDÆ, or Crab family, are found in a high state of preservation in the eocene clays of Sheppey and in the Bognor beds at Alum Bay, Isle of Wight, and in strata of the same age in France.

CLASS IV.—ARACHNIDA.

The Spiders have the head and thorax united and covered by a cephalo-thorax. They have four pairs of feet. The tegumentary skeleton is in general solid; the higher forms breathe by simple internal sacs or lungs, the inferior forms by trachea. The simple eyes, in general eight in number, are disposed around the antèrior part of the cephalo-thorax. We find very few members of this class in a fossil state in the older rocks; but the presence of *Cyclopthalmus*, a genus of SCORPIONIDÆ in the carboniferous stage of Bohemia,

* Mantell's Isle of Wight.

proves that the Arachnida were represented in the fauna ot the primary epoch, and supplies another link to the chain of evidence afforded by the flora of that stage, that the temperature of the centre of Europe resembled that of our tropics at the time when the coal plants flourished. Fossil spiders are found in the yellow amber of Prussia. Koch and Berendt have described one hundred and twenty-three species belonging to fifty genera, of which thirteen are extinct, whilst none of the species are identical with those now living.

Class V.—MYRIAPODA.

The Centipedes have the body composed of twenty-four feet or upwards. All the members of this class are terrestrial, and breathe by trachea. They live concealed under stones, moss, or the bark of trees. Extinct genera of Iulidæ and Scolopendridæ have been found with those of the preceding class by the same observers.

Class VI.—INSECTA.

The Insects have the body divided into head, thorax, and abdomen. The head is formed by the fusion of several elements, and supports the eyes, the antennæ, and the parts of the mouth. The thorax is composed of three segments soldered together; the *pro-thorax*, or anterior; *meso-thorax*, or middle; and *meta-thorax*, or posterior. Each segment supports one pair of articulated feet; and the pro-thorax and meso-thorax the first and second pairs of wings, when they exist.

The abdomen consists of a series of simple rings, moveable on each other, and without appendages, except the last pair, which are sometimes provided with special organs. The tegumentary skeleton is indurated with *chitine*, which has a firmness equal to that of horn. Insects breathe by stigmata or air-holes situated on the sides of the rings, and by trachea or air-tubes, that ramify through all parts of their bodies. We find representatives of most of the orders in a fossil state.

Order Diptera (or Flies).—Have two membranous wings, articulated to the pro-thorax, and rudimentary wings or balancers to the meta-thorax.

The insect limestone of the lower and upper lias of Gloucestershire, the limestones of the Oxford stage of Solenhofen, and the wealden beds of Wilts, have yielded beautiful specimens of wings. Many genera of this order are preserved in the tertiary strata, and entire specimens are enclosed in amber.

Order LEPIDOPTERA (or Butterflies).—Have the mouth provided with a long proboscis coiled into a spiral form; they have four wings clothed with microscopic scales attached to the membrane by a pedicle: the lithographic limestones of Solenhofen contain the impressions of a genus of this order. A few wings have been found in the tertiary strata of France: they are rare in amber.

Order HEMIPTERA (or Bugs).—Are suctorial insects, provided with an articulated proboscis. They have four wings: the anterior pair are in part indurated; the posterior pair are membranous: their remains are found with the preceding.

Order HYMENOPTERA (or Bees).—Remarkable for the social instincts of many of its families, have four transparent membranous wings, and a firm tegumentary skeleton: they are found with the preceding orders.

Order NEUROPTERA (or Dragon-flies).—Have four nearly equal wings, the nervures or framework of which are well developed; their integuments are delicate, and most of their larvæ are aquatic. One genus, *Corydalis*, is found in the carboniferous stage of Coalbrook Dale. In the lower and the upper beds of the liasic stage in Gloucestershire and Warwickshire numerous beautiful wings of *Æshna* have been found. The annexed figure is from a specimen obtained from the lower lias near Bidford in Warwickshire, and described by H. E. Strickland, Esq.* Fig. 178 shows the

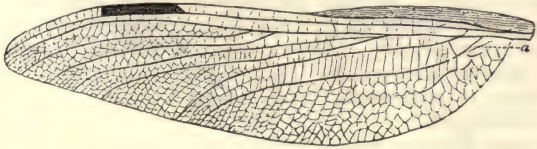


FIG. 178.—Fossil wing of Æshna liassina. Strickland.

* Magazine of Natural History, new series, vol. iv. p. 302.

structure of *Æshna liassina* of the natural size; fig. 179, that of the recent *Æshna grandis*, and fig. 180, *Libellula depressa.* The dimensions of the fossil are about one-third greater than those of *Æ. grandis*, the largest of our British species; its length being 2 inches 10½ lines, and its greatest breadth 8½ lines.

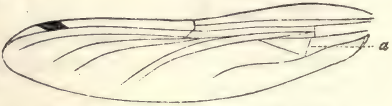


Fig. 179.—Wing of Æshna grandis.

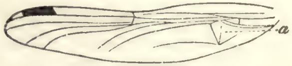


Fig. 180.—Wing of Libellula depressa.

Æshna Brodei, was found in the upper lias of Dumbleton, in Gloucestershire.*

The Rev. P. B. Brodie † found, in the same beds, an unique specimen of *Heterophlebia*, with the head, thorax, and half of the abdomen, and with the four wings expanded, and beautifully preserved. In the Stonesfield slate is found a portion of a wing of a large *Hemeroboïdes*. The lithographic schists of Solenhofen have yielded many specimens of large Neuroptera, which have been described by Count Münster. The lacustrine tertiary strata of France contain tubes that have been attributed to the larvæ of Phryganiæ (caddis-worm) (fig. 181).


Fig. 181.—Caddis-worm.

Berendt found genera belonging to the Termites, Ephemeridæ (May-flies), and Phryganidæ, in the yellow amber of Prussia.

Order ORTHOPTERA (Grasshoppers).—Have the anterior wings modified into thin elytra; inferior in their development, however, to those of beetles. The two posterior pair are membranous, and when in a state of repose, are folded longitudinally. The mouth is armed with mandibles and maxillæ formed for mastication. The tegumentary skeleton is moderately solid. The feet are strong and well developed.

Count Münster found *Cridites* and *Blatlina* in the carboniferous stage of Germany.

* Proceedings of the Geological Society, 1843.

† Geological Journal, vol. v. p. 31.

Fossil Crust

Mantidæ and Locustidæ, in the Oxford stage of the oolites of Bavaria. *Gryllus*, *Gryllotalpa*, and *Locusta* have been found in the tertiary strata of France and in the yellow amber of Prussia.

Order COLEOPTERA (Beetles). Have the anterior pair of wings developed into horny cases or *elytra*, under which the posterior pair of membranous wings are folded. Their skeleton is very solid: their mouth is provided with a pair of maxillæ and a pair of mandibulæ, disposed for mastication. This order is one of the most numerous at the present day, and to it belongs many fossil insecta.

At the close of the palæozoic epoch coleoptera existed. Curculionidæ were found in the carboniferous stage at Coalbrook Dale.

The inferior beds of the lias of Gloucestershire and Worcestershire have yielded many genera and species. These are figured and described by the Rev. P. B. Brodie in his valuable monograph,* to which we refer the student for ample and interesting details. In a thin seam of cream-coloured insect limestone, which lies at the base of the liasic stage, that accurate observer found genera belonging to the families Buprestidæ, Curculionidæ, Carabidæ, Telephoridæ, Elateridæ, Chrysomelidæ. In a thin seam of limestone in the upper lias, many wings of coleoptera associated with the remains of fishes have been found. From the Stonesfield slate of Gloucestershire were obtained genera belonging to the families, Prionidæ, Blapsidæ, Buprestidæ, Chrysomelidæ.

From the lithographic schists of Solenhofen, Count Münster and M. Germar have obtained and described fine specimens of *Cerambycinus*, *Buprestes*, *Scarabæides*. In the wealden of Wiltshire, Mr. Brodie found genera belonging to the families Carabidæ, Staphylinidæ, Tenebrionidæ, Harpalidæ, Elateridæ, Curculionidæ, Cantharidæ, Hydrophilidæ, Helophoridæ.

* A History of the Fossil Insects of the Secondary Rocks of England.

FOURTH DIVISION.

VERTEBRATA, *Cuvier*. SPINI-CEREBRATA, *Grant*.

This great division comprehends all animals that have an internal articulated skeleton, symmetrical in the disposition of its elements, and destined to protect the brain and spinal cord, lodge the organs of the special senses, and form a framework for the organs of locomotion.

Bone is composed of an animal substance, in the interstices of which earthy salts, chiefly the phosphate of lime, are deposited. A thin slice of bone, mounted in Canada balsam, and examined by a good microscope, with a power of two hundred linear, exhibits in a very satisfactory manner the osseous structure. It is seen to be composed of a number of openings in a delicate transparent membrane. The openings are transverse sections of canals that everywhere traverse bone, and are called Haversian, after their discoverer.

Around each canal we observe a number of fine concentric lines, each line having a laminated structure; between the laminæ a number of singular spider-like bodies are situated. These are the bone-cells, which are in general oval, and have a number of microscopic tubes radiating from their circumference. In recent bones the cells are transparent, but in fossil bones they are always opaque, and the same has been observed in the bones of mummies. In the one case the process of fossilisation, in the other the percolation of bituminous matter, has injected the cells through the small tubes that communicate with the Haversian canals.

Mr. John Quekett has shown, in a valuable paper on the intimate structure of bone, that the bone-cells of each class of the Vertebrata have forms and dimensions that are special to each. The bone-cells of the Mammalia average about $\frac{1}{2000}$ of an inch in the long diameter; and if we take this as a standard of comparison, we find that the bone-cells of birds will fall below it, and the bone-cells of reptiles will far exceed it; whilst those of fishes are so entirely different from mammals, birds, and reptiles, both in shape and size, that they

cannot be mistaken for either. By microscopic examination we are thus enabled to show that the physiological laws relating to the structure and growth of bone have ever been the same from the first creation of vertebrate animals in the far remote period, when fishes were introduced into the seas of the Silurian and Devonian eras, down to the present hour; that the colossal *Iguanodon* was provided with bone-cells formed after the same type as the tiny lizard that crosses our path; that the bones of the gigantic *Dinornis* exhibit no difference in structure from those of its representative, the *Apteryx;* that the bones of the *Mastodon* and *Megatherium*—those terrestrial giants of the pre-Adamite earth—are modelled after the type which we see in our domestic quadrupeds, and in man himself.

The following table, from the above-mentioned paper,* shows the measurement of the bone-cells in Fishes, Reptiles, Birds, and Man.

MEASUREMENT OF THE BONE-CELLS IN PARTS OF AN ENGLISH INCH.

(Transverse sections.)

HUMAN	Long diameter	One of the largest	$\frac{1}{1440}$
		One of the smallest	$\frac{1}{2400}$
	Short diameter	One of the largest	$\frac{1}{4000}$
		One of the smallest	$\frac{1}{8000}$
OSTRICH	Long diameter	One of the largest	$\frac{1}{1333}$
		One of the smallest	$\frac{1}{2250}$
	Short diameter	One of the largest	$\frac{1}{5425}$
		One of the smallest	$\frac{1}{9650}$
TURTLE	Long diameter	One of the largest	$\frac{1}{375}$
		One of the smallest	$\frac{1}{1150}$
	Short diameter	One of the largest	$\frac{1}{4500}$
		One of the smallest	$\frac{1}{5840}$
CONGER EEL	Long diameter	One of the largest	$\frac{1}{550}$
		One of the smallest	$\frac{1}{1135}$
	Short diameter	One of the largest	$\frac{1}{4500}$
		One of the smallest	$\frac{1}{8000}$

* Transactions of the Microscopical Society, vol. ii. part ii. p. 46.

The skeleton is divided into three distinct parts:—the HEAD, the TRUNK, and the EXTREMITIES (fig. 182).

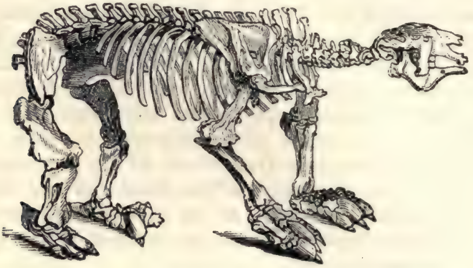


FIG. 182.—The Megatherium.

The *head* is composed anteriorly of the *face*, formed of two jaws, of which the lower is moveable; of the orbital cavities or sockets for the eyes; and posteriorly of the *cranium*, or osseous case for lodging and protecting the brain. The *trunk* is supported by the spinal axis, composed of a series of separate bones called vertebræ, which are moveable on each other, but firmly united together by joints, ligaments, and a connecting substance. To the central part or body of each vertebra is articulated an arch of bone for lodging and protecting the spinal cord. The first vertebra carries the skull, and the posterior vertebræ are often prolonged into a tail. To the sides of some of the vertebræ are attached *the ribs*, which form a cage for lodging and protecting the organs of respiration, circulation, and often those of digestion. The ribs are for the most part united before to a breastbone or *sternum*. The *extremities*, when they exist, never exceed two pairs, but the posterior pair, or both, are sometimes absent.

The Vertebrata are divided into four classes:—*Fishes, Reptiles, Birds, Mammifera.*

Class I.—FISHES.

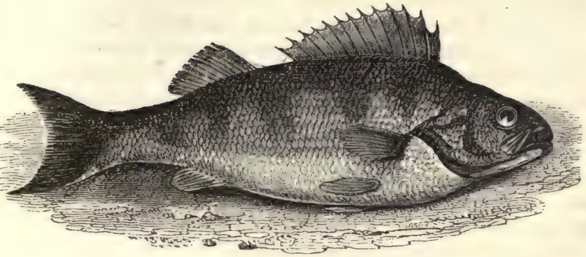


Fig. 183.—Perca fluviatilis.

Fishes are organised for an aquatic life, and respire by gills or branchiæ. Their heart receives only venous blood from the body, which it propels through the organs of respiration, to be submitted to the influence of the oxygen of the water. The general circulation through their bodies is maintained by a contractile dorsal vessel.

The body of the fish is formed so as to give the least possible resistance to the medium it inhabits. It is furnished with fins, which balance and guide its movements, the propulsion through the water being effected for the most part by the action of the inflector muscles of the tail. The fins consist of a fold of the integument, sustained by osseous or cartilaginous pieces, called rays, which are either articulated to the vetebral column or to the bones of the anterior or posterior extremities. Some of the fins are placed on the median line of the back, abdomen, and tail, as the *dorsal*, *anal*, and *caudal*. Others, as the *pectoral* and *abdominal*, are disposed in pairs, and represent the extremities (fig. 183). The bones of fishes are either osseous or cartilaginous, as they have a greater or lesser proportion of earthy matter in their composition. They have no medullary cavity. They contain less gelatine, have a larger proportion of water, and are less dense and compact in their texture than those of the higher classes. The bones of fishes resemble those of the embryo

of reptiles and mammals, in having the component elements of many parts of their skeleton permanently separable from each other; a circumstance which renders the study of their osteology, especially that of the skull, a matter of much difficulty.

Many of the numerous bones which the student meets with in the cranium of fishes, are detached elementary parts of the cranial vertebræ, which are united to their neighbouring elements in the cranial vertebræ of reptiles and quadrupeds.

The bodies of the spinal vertebræ are formed of concentric layers, which are broadest at the circumference, and are narrowest at the centre. They are therefore doubly concave, and are readily identified in a fossil state by this character alone.

The skin of fishes is covered with scales, which contain about forty-six per cent. of the phosphate of lime; so that scales in reality resemble bone in composition. In this respect they differ essentially from the horny covering of reptiles. In consequence of the scales of fishes being found preserved when all other parts of their structure have disappeared, a new arrangement of this class has been made, which is based on the organisation of their dermal covering.

The teeth of fishes present great varieties, as regards their number, form, and structure, so that no general description can possibly convey a correct idea of their dentition; and as our limits prevent us from entering into details, we must direct the student to the best sources of information. Professor Owen's "Lectures on Comparative Anatomy," vol. ii. lect. 9, contains a valuable summary on the subject, and more elaborate details will be found in his great work on Odontography. Professor Rymer Jones's article, *Pisces*, in the "Cyclopædia of Anatomy," ought likewise to be consulted. But the student would do well to procure very thin vertical and transverse sections of the teeth of the different orders and families of fishes, mounted in Canada balsam, which he ought to study attentively with the microscope. Figures and descriptions are very good, but the natural objects are far better; and these preparations will at the same time form good standards for the comparison of fossil specimens. The Cuvierian classification of fishes, although

admirably adapted for living forms, was neither sufficient nor applicable in all cases to the fossil remains of this class. It occurred, therefore, to Professor Agassiz, the great master of this branch of Palæontology, that, as the scaly appendages of the tegumentary membrane were often preserved in a fossil state when the other structures of the fish had perished, that the scales would afford the palæontologist the surest basis for the division of the class into orders and families. Moreover, as the tegumentary covering of the vertebrated animals harmonises so completely with the other parts of their economy as to be in fact the outward reflection of the internal organisation, the modifications in the structure of the *exoskeleton* were taken as the basis of the new classification. On this principle, Agassiz divided the class into four orders :—

I. The first order, or Placoid, comprises those so termed from πλαξ, a broad plate; they have the skin *irregularly* covered with plates of enamel, sometimes large, as in the rays, sometimes reduced to small points, as in the sharks. (Fig. 184.)

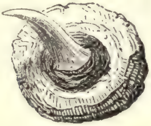


Fig. 184.

Fig. 185.

II. The second order, or Ganoid, so called from γανος, splendour, because they are covered *regularly* with angular scales, composed of horny or bony plates, coated externally with a bright enamel. (Fig. 185.)

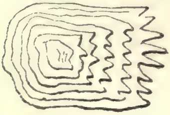


Fig. 186.

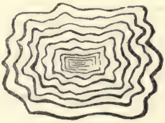


Fig. 187

III. The third, or Ctenoid, from κτεις, a comb, includes such as are characterised by scales, jagged or denticulated on the posterior margin, as in the perch. (Fig. 186.)

IV. The fourth order, or CYCLOID, from κυκλος, a circle, have scales smooth and simple on the margin, and often ornamented with various figures on their upper surface. The herring and the salmon are examples. (Fig. 187.)

As the secondary epoch is called the "age of *Reptiles*," the primary epoch may, with equal justice, be denominated the age of *Fishes*. They were the only vertebrate animals in the ocean that deposited the palæozoic rocks, and were the tyrants of the seas of those remote periods. At the commencement of the secondary epoch, the dominion of the waters was shared between them and the ancient reptiles. During the oolite period, they became subordinate to that class, and their numerous genera afforded nourishment to the marine Saurians, which flourished to the close of the secondary epoch.

Order PLACOID, AGASS.—Have the body covered with horny plates instead of scales, which are often armed with a median spine, or are bristled with small eminences like a rough file, as in the *shagreen* of sharks. (Fig. 184.)

The skeleton is soft and cartilaginous, and with the exception of the bodies of the vertebræ, the teeth, rays, and tegumentary plates, we seldom find it preserved in a fossil state. It is on the form and structure of these fragments, therefore, that the fossil genera have been established by Agassiz.

1st Family.—The RAJACIDÆ, of which the ray is typical, have the body depressed in the form of a disc, and covered with spiniferous plates. The genera of this family are thus distributed: *Ptychacanthus* in the Devonian, *Pleuracanthus* in the carboniferous, and palæozoic, *Squaloraya*, and *Cyclarthrus* in the liasic, *Asterodermus*, *Euryarthra* in the Oxford stage of the oolites. Three are found in the eocene, and three in the newer tertiary strata. Of these twelve genera, seven are extinct, and five are living.

2nd Family.—The PRISTIDÆ have the saw-fish for their type. The bones of the face are developed into a long projecting blade, armed laterally with osseous spines. An extinct species of *Pristis* is found in the Paris beds.

3rd Family.—The CESTRACIONIDÆ have the body elongated, the teeth flat, and embedded, like a tesselated pavement, in the jaw. Of this family we know only one living genus, *Cestracion* (the Port Jackson shark), and fourteen

fossil genera. To this family belong the large flat teeth (*Acrodus nobilis*) met with in the lias.

4th Family.—The Hybodidæ, the type of which is *Hybodus*, an extinct genus, allied to the sharks, with conical, but not compressed, teeth. The genera are distributed in the different stages from the carboniferous to the neocomian.

5th Family.—The Squalidæ, have for their type the

Fig. 188.—Tooth of the Fossil Genus, *Otodus*.

Squalus, or shark, of our seas. Characterised by their elongated body, adapted for rapid motions, by their sharp, triangular, lancet-shaped teeth. Twenty fossil genera have been identified. Figs. 188 and 189 show the forms of the teeth in *Otodus* and *Lamna*.

6th Family.—The Chimæridæ, have for their type the *Chimæra* of our seas. The fossil genera commence in the oolitic, but are most abundant in the tertiary strata. None

of the seven fossil genera of this family have any living representative.

FIG. 189.—Teeth of Lamna.

(*a* & *d*) Teeth of *Lamna*, agreeing in form with species abundant in the London clay and red crag.
(*b*) Tooth probably of the same genus, but of an undescribed species, provided with quadrate lateral denticles.
(*c*) Tooth of *Lamna* with two pairs of denticles.
(*e*) A tooth, of which the form probably depends upon its situation having been near the termination of the series.

ICHTHYODORULITES are the spines of the dorsal fins of placoid fishes. On the form and structure of these singular bodies, several new genera have been established.

The Order GANOID, Agass.—Have the body enclosed in a coat of mail formed of the scales. These are composed of two substances—an internal horny or osseous lamina, and an external layer of hard enamel, brilliant and polished like the surface of the teeth. The scales are generally of an angular or rhomboidal form; they are regularly united by their margins, and lock into each other in a singular and complicated manner, by a spine and socket.

The bones of the skeleton are more dense than in the placoids, but they are not so completely ossified as in the other orders. In the *Sturgeon* the skeleton is cartilaginous.

1st Family.—The ACIPENSERIDÆ, of which the Sturgeon is the type, have the body protected by ranges of dermal plates. We know two genera. A fossil species of *Acipenser*

is found in the eocene of Sheppey; and *Chondrosteus* is found in the lias of Lyme Regis.

2nd Family.—The SYNGNATHIDÆ, of which *Syngnathus* is one of the types; they are encased in a cuirass of bony plates, of a form which gives the body an angular figure. This family includes many living, and two fossil genera from the beds of Monte-Bolca.

3rd Family.—The DIODONTIDÆ—Have the jaws covered with enamel, which represent the teeth. Their scales develope long spines. We know many living genera and a single fossil *Diodon* from the tertiary strata.

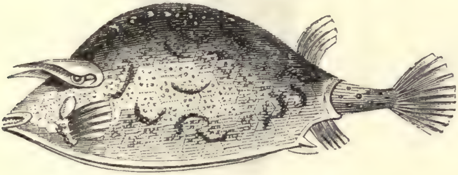


FIG. 190.—Ostracion quadricornis.

4th Family.—The OSTRACIONIDÆ, of which the Trunk-fish *Ostracion* (fig. 190) is typical. The body is encased in an osseous box, formed of polygonal plates. Fossil genera of this family are found in the cretaceous and tertiary strata.

5th Family.—The CEPHALASPIDÆ have the head and the anterior part of the body covered with osseous plates, which sometimes form a complicated cuirass. They have a heterocercal tail, or that organ is absent; the head is flat and round; the mouth is situated at the under surface of the head, and is often without teeth; the body is flat; the pectoral fins are sometimes greatly elongated in some genera and absent in others; the ventrals are always deficient; the skeleton is very simple and reduced to a rudimentary development of its peripheral parts; the dorsal cord is persistent through life, to which are attached bony processes. It is remarkable to find in the adult condition of this ancient family several of the phases of structure which all fishes exhibit in the course of their embryonic development. The several genera of which it is composed have been a great puzzle to palæontologists; their remains, when first dis-

covered, having been regarded as trilobites by some, and referred to the class of insects by others. For an admirable

FIG. 191.—Coccosteus cuspidatus: Agass.

description of the *Cephalaspidæ*, graphic beyond all praise, the student should consult Hugh Miller's "Old Red Sandstone." The five genera it contains are limited to the Devonian

system. They are *Cephalaspis, Coccosteus* (fig. 191), *Pterichthys* (fig. 192), *Polyphractus*, and *Pamphractus*. The old red sandstone of Scotland and England has yielded these precious relics; many specimens of which are now in the British and other Museums.

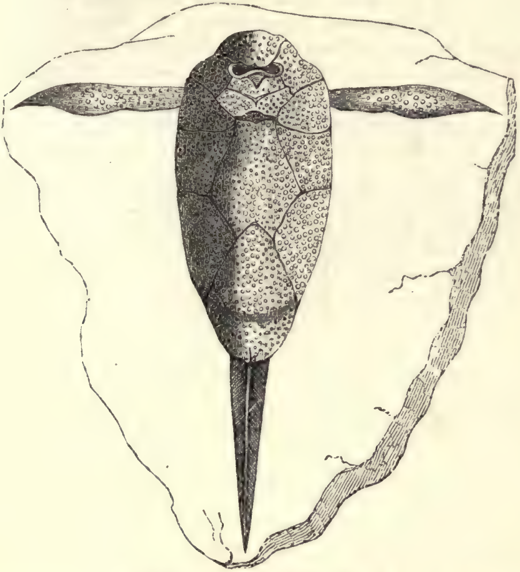


Fig. 192.—Pterichthys: Agass.

6th Family.—The Pycnodontidæ—Have broad or round teeth embedded in the jaws. The genera range from the triasic and oolitic to the tertiary period; none now exist.

7th Family.—The Celacanthidæ—Have the bones of the skeleton, especially those of the rays, in the form of hollow tubes; the tail fin is very peculiar; the spinal column is prolonged through the middle part thereof to form a long style, and the rays are carried on a separate range of interapophysal bones; their dentition resembles the preceding family. The twelve genera which belong to it range between the Devonian and cretaceous periods.

8th Family.—The ACROLEPISIDÆ—Include the great sauroid fishes, with heterocercal tails, and large pointed conical teeth alternating with smaller ones. The genera *Saurichthys* and *Megalichthys* were the tyrant monsters of the waters they inhabited. Five of the twelve genera it includes appeared for the first time in the Devonian group; they attained their greatest development in the carboniferous stage, and became extinct with the triasic.

9th Family.—The POLYPTERIDÆ—Are sauroid fishes, with homocercal tails. Of the sixteen genera of this family, fourteen are extinct, and two are still living. They were created at the commencement of the oolitic period, after the last heterocercal sauroids had become extinct. They are most abundant in the Oxford and upper stages of the oolitic period, and are found in the chalk. The *Polypterus* of the Nile, and the *Lepidosteus*, or bony pike, of the American lakes and rivers, are the living types.

10th Family.—The DIPTERIDÆ resemble the ACROLEPISIDÆ, in the form of the tail, and of their scaly armour; but they possess two dorsal and two ventral fins. We find two genera—the *Osteolepis*, in the Devonian stage: and the *Dipterus*, in the carboniferous.

11th Family.—The ACANTHODIDÆ have the tail heterocercal; the teeth unequal, and the body covered with microscopic scales. The four genera of this group are Devonian—one passes into the carboniferous stage, but the family became extinct at the close of the palæozoic epoch.

12th Family.—The PALÆONSICIDÆ comprehends the Lepidoïd fishes with heterocercal tails; they have small teeth arranged on many lines in the interior of the mouth; the scales are rhomboidal in form, and are arranged in parallel lines on the body; they have one dorsal and one ventral fin. We know six genera; five commenced with the carboniferous stage, of which three passed into the triasic, and one is special to the Oxford oolite.

13th Family.—The LEPIDOTIDÆ embraces the Lepidoïd fishes with homocercal tails. The ten genera which compose it are all extinct; seven genera are found in the lias. It attained its maximum development of species in the Oxford stage. In the cretaceous strata there are three, and in the inferior tertiary, only one, the *Lepidotus*.

The Order CYCLOID.—Have the body covered with circular or elliptical scales of a simple horny or osseous structure

FIG. 193.—The Pike (*Esox lucius*).

without enamel, and with the posterior border nearly smooth. The external surface of the scale is often marked in relief, with the lines of growth (fig. 187). The scales of the lateral line form tubes through which the mucus flows, that varnishes the surface of the body of these fishes. The skeleton is osseous. This order includes many of the *malacopterygiens* and *acanthopterygiens* of Cuvier; the Salmon, the Carp, and the Pike (fig. 193), may be regarded as its typical forms. The cycloid order was created during the deposition of the flinty chalk of the cretaceous period. It contains no extinct family, but a great number of extinct genera which are most numerous in the ancient strata. Thus nearly all the cycloid genera of the chalk are extinct, and more than one half of those of Glarus and Monte-Bolca are so likewise. As we ascend through the tertiary stages, the extinct genera diminish, and the cycloid ichthyolites of these beds belong for the most part to extinct species of existing genera.

Order CTENOID.—Have horny scales, composed of plates: the posterior borders of which are denticulated; the plates are of unequal size, and are super-imposed on each; and as the inferior always exceeds the superior layer, the

points of the denticulations render the scaly surface of the fish rough to the touch (fig. 186). The skeleton is osseous, and the Perch is typical of the order. The ctenoids were created towards the close of the cretaceous period. Their remains are found in the upper stages of the chalk of England and Germany. The schists of Glarus contain great numbers. They are abundant in the strata of Monte-Bolca, the London clay, and the Parisian tertiaries. The gypsums of Aix and the fresh-water strata of Œningen contain numerous species. Almost all the genera of this order found in the cretaceous rocks are extinct, and more than half the genera found at Monte-Bolca are so likewise, whilst in the upper stages of the tertiary period the fossil species belong to extinct forms of existing genera.*

The profound researches of Professor Agassiz on fossil fishes have enabled that learned zoologist to deduce certain important generalisations from their palæontological history, a condensation of which we shall endeavour to embody in our *resumé* of the class.

The *Placoids*, among which are the rays and the sharks, were created at the commencement of the palæozoic epoch, and were introduced into the seas that deposited the Silurian rocks. They attained the maximum of their generic development in the carboniferous stage. They diminished in the triasic, were again augmented in the oolitic, and remained stationary to the close of the tertiary epoch. The rays and the sharks are the only representatives of this group in our modern seas. We conclude, therefore, that from the close of the palæozoic or first great epoch of the animalisation of our globe, down to the present time, the placoid fishes have exhibited an order of decadence, both as regards the number of the families and the genera they contain.

The *Ganoids*, which include the *Polypterus* and *Lepidosteus*, have obeyed a law of development nearly akin to that which regulated the decline and fall of the placoids. The palæozoic rocks contain thirty-four genera of ganoids, of which twenty-eight belong to the Devonian stage. They diminish in numbers in the triasic, and attain their maximum development

* As the *Cycloid* and *Ctenoid* orders contain no extinct families, we have omitted the description thereof; for which consult "Cuvier's Règne Animal," and "Agassiz's Poissons Fossiles."

in the oolitic period, the different stages of which contain thirty-five genera of this order. They greatly decrease in numbers in the cretaceous and tertiary strata, and have a few representatives in our seas. We conclude, therefore, that with the close of the oolitic period, the ganoids commenced their decline.

The *Cycloids*, which include the carp and the pike, present a remarkable contrast to the placoids and ganoids; for none of the fossil fishes found in the palæozoic, triasic, or oolitic strata, belong to the cycloid order. Their creation dates from the commencement of the newer stages of the cretaceous period. They were introduced into the seas that deposited the upper beds of the white flinty chalk. They increased in numbers in the tertiary strata, and have attained their maximum development in our modern seas. All the fossil genera appertain to families now living.

The *Ctenoids* followed the cycloids in their geological march. They commenced their career with a few genera in the upper stage of the chalk. A great many genera are found in the tertiary strata, but their maximum development has taken place in the modern epoch. Like the cycloids, all the fossil genera belong to existing families.

From this comparative view of the four orders of fishes, we learn that the placoids and ganoids had their greatest development in the seas of the past, whilst the cycloids and ctenoids have their maximum development in the waters of the present epoch. Four-fifths of the fishes now living belong to the cycloid and ctenoïd orders; the remaining fifth consists of placoids and a limited number of ganoids. Unlike the mollusca, whose generic forms have lived through many successive periods, the different faunas of fishes are separated from each other by well-defined genera. Each type appears to have been destined to exist for a limited time, as the entire creation of one epoch differs from that of another.

Thus no fossil fish obtained from strata anterior to the chalk is identical with any genus now living. All these ancient fishes differ from those of our modern seas by well-defined structural characters.

The number of extinct genera is very considerable even in strata that are regarded (speaking comparatively) as modern. Thus the fishes of Glarus and Monte-Bolca,

referred to the eocene stage of the tertiary period; of these, one half of the genera are now extinct, whilst in the newer stages of this period nearly all the fossil species belong to existing genera.

In the strata anterior to the lias, almost all the fishes had heterocercal or unilobed tails (fig. 194); that is to say, the spinal vertebræ were prolonged into the upper lobe of that organ, as seen now only in the family of sharks, of which the dog-fish of our coasts is an example. Whilst from the lias upwards the tails of the majority of fishes were bilobed or homocercal. (Fig. 195.)

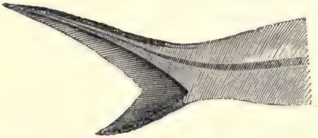


FIG. 194.—Heterocercal; Shark.

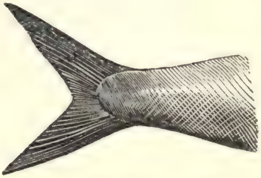


FIG. 195.—Homocercal; Herring.

As the ancient fishes have left their remains in the rocks of all epochs, they afford a satisfactory demonstration of the law which limits fossil forms to different stages of the earth's history. Of the one thousand fossil species at present known, not one is identical with any species now living, and none of the fossil species pass from one stage to another.

The history of fossil fishes affords an unanswerable argument against the hypothesis, that a gradual development in the species of animals has taken place during past ages; an idea now better known as the development theory. We have seen that the fossil fishes belonging to the placoid and ganoid orders, which are in fact the most highly organised types of the class, approached reptiles in some important points of their anatomy; that these highest orders maintained their dominion during the deposition of the palæozoic, triasic, and oolitic strata, and preserved their typical structure through all the changing conditions to which they were exposed. The cycloid and ctenoid orders were not created until towards the close of the cretaceous period; their organisation being inferior to the placoids and ganoids, they

could only have appeared by a special act of creation, as it would be fatal to the hypothesis of development to admit that higher organisms could become the progenitors of lower forms.

In fine, the history of fossil fishes supplies abundant evidence in support of the opinion that the Almighty has, from time to time, created those forms of life which were best adapted to the changing conditions of the earth's surface. Hence we see families and genera appearing in great numbers, destined to live for a limited time, and to become extinct with the close of the stage they characterise.

Class II.—REPTILES.

The class Reptilia is one of the most interesting to the palæontologist, as the fossil remains of many of its extinct forms present, in some, remarkable adaptations of structure to their mode of life, in others dimensions so gigantic, and in all, a geographical distribution so different from the actual condition of nature, that we enter upon the inquiry with an enthusiasm equal to the novelty of the subject.

The class is divided into four Orders :—The Chelonians, or *Tortoises;* the Saurians, or *Lizards;* the Ophidians, or *Serpents*, and the Batrachians, or *Frogs* and *Salamanders*. This class comprehends all the vertebrated animals with cold blood, whose respiration in the adult state (if not in early life) is aërial and incomplete. The head is small, and the body is for the most part much elongated. The extremities are sometimes rudimentary or absent, as in serpents, but in general they are four in number, and are adapted for walking, swimming, or flying. All the parts of the skeleton present important modifications in the different orders.

The skull is always small and the face elongated. The lower jaw is composed of several pieces, and is articulated to the upper jaw by a distinct bone (the tympanic); sometimes this bone is a moveable lever for the purpose of increasing the gape. The upper jaw is in general immoveable. In some reptiles, as the lizards and the tortoises, the lateral bones of the skull arch over and cover the temporal bones, and thus make their cranium appear much larger than it in reality is. The skull is in general slightly moveable, and

is articulated to the vertebral column by a single condyle with several articulating surfaces.

The bones of the trunk present many modifications in their form and arrangement. In the lizards, the ribs are more numerous than in birds and mammals, and they extend around the abdominal as well as the thoracic organs. In serpents, the sternum is absent, and the ribs are important instruments for locomotion, when added to the ball and socket mode of articulation of the spinal column. Their number is very considerable, amounting in some to 300 pairs.

In the frogs the converse of this type is found. The ribs are absent, and the sternum is greatly developed, to form with the bones of the shoulder a girdle for the articulation of the anterior extremities.

In the tortoises, the thoracic and abdominal organs are inclosed in an osseous case, into which likewise the head and extremities can be withdrawn. It is formed of two shields, the dorsal or *carapace*, and the ventral or *plastron*, joined together at the sides. The expansion of the ribs forms the carapace, and the elements of the sternum the plastron. This cuirass is externally coated with large scaly plates.

The extremities present modifications corresponding with their varied modes of life. Thus, in the land tortoises and lizards they are constructed for walking. In the chameleon the bones of the hand are arranged in two divisions for grasping, like a forceps, the branches of the trees in which they live. In those formed for an aquatic life, the extremities are converted into flat oars for swimming. Such is the case in the marine turtles, and in the ancient marine saurians, the ichthyosaurus and plesiosaurus. Those which are destined for an arborial life have the skin of the flanks stretched out upon the six false ribs which extend horizontally outwards to form a parachute for sustaining the lizard whilst leaping from branch to branch. Other extinct forms, the pterodactyle, had one finger of the hand enormously developed into a rod for supporting a true wing like the bats.

In consequence of the arterial blood of reptiles being always mixed with a proportion of venous blood, the temperature of their bodies is nearly that of the surrounding medium. Their organic functions are, therefore, much influenced by changes of temperature. Cold greatly dimi-

nishes the action of the heart and lungs, slackens the play of all the vital organs, and produces a state of hyberna-tion. A diminution of the temperature to about 40° to 50° is almost always fatal to these animals. It is important to bear this physiological law of their economy in recollection when reasoning on the past conditions of the earth in those latitudes where reptile remains are discovered entombed.

The skeletons of reptiles are found nearly entire in the liasic beds of the oolitic period and in other secondary rocks. We refer the student who is anxious to become acquainted with the marvellous structure of these denizens of the ancient earth to the magnificent specimens contained in the British Museum, and in those of Bristol and Cambridge.

The lacustrine eocene strata of Hampshire and the Isle ot Wight have yielded nearly perfect carapaces of turtles and the skulls of crocodiles and an alligator. The eggs of chelone are found in the falunian stage of the Gironde, and the coprolites of this class are strewed through many rocks of the oolitic and cretaceous periods, and the foot-prints of

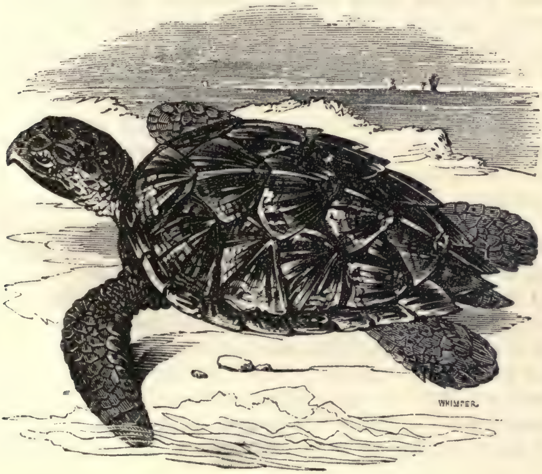


FIG 196.—The Green Turtle (*Chelonia midas*).

reptiles are preserved in the new red-sandstone of Scotland, England, Germany and America. "The historian or the antiquary may have traversed the fields of ancient or of modern battles, and may have pursued the line of march of triumphant conquerors, whose armies trampled down the most mighty kingdoms of the world. The winds and storms have utterly obliterated the ephemeral impressions of their course. Not a track remains of a single foot, or a single hoof, of all the countless millions of men and beasts whose progress spread desolation over the earth. But the reptiles that crawled upon the half-finished surface of our infant planet, have left memorials of their passage, enduring and indelible.

"No history has recorded their creation or destruction; their very bones are found no more among the fossil relics of a former world. Centuries and thousands of years may have rolled away between the time in which these footsteps were impressed by tortoises upon the sands of their native Scotland, and the hour when they are again laid bare, and exposed to our curious and admiring eyes. Yet we behold them, stamped upon the rock, distinct as the track of the passing animal upon the recent snow, as if to show that thousands of years are but as nothing amidst eternity, and as it were in mockery of the fleeting perishable course of the mightiest potentates among mankind." *

First Order.—CHELONIA. Have the ribs transformed into a *carapace*, and the sternum into a *plastron*, to form an osseous case for containing the organs of circulation, respiration, and digestion. The extremities are constructed for a terrestrial or an aquatic life, and the carapace and plastron present modifications which characterise the terrestrial, palustrine, and marine families.

1st Family.—The TESTUDINÆ, or land tortoises, are characterised by the height and solidity of the carapace, which is covered with a variable number of non-imbricated scales. The parts which correspond to the vertebræ have five plates; there are four on each side covering the ribs, and twenty-three disposed around the border, $5+8+23=36$. The toes are short, united to their extremities, and are adapted for

* Dr. Buckland's Bridgewater Treatise, p. 263.

walking. To this family are referred the foot-marks found on slabs of new red-sandstone in the quarries of Corn Cockle Muir, Dumfries-shire.* Bones of *Testudo* have been found in the great oolite of England, the chalk of America, and in the tertiary strata of France. Fragments of an extinct genus, *Megalochelys*, have been discovered in India by Cautley and Falconer, in the newer tertiary bed of the Himalaya. The bones justify the inference, that the carapace of this giant was about twenty feet in length; the remains of tortoises have been found by Weiss with the bones of the megatherium, in South America.

2nd Family.—The EMYSIDÆ, or Marsh Tortoises, have the carapace of an oval form, solidly articulated, but more depressed than that of the Testudinæ. The toes, four to five in number, are long and distinct, and united at their base by a membrane to adapt the extremities for swimming. This family contains extinct and living genera. The extinct genera are *Idiochelys*, from the Oxford stage of Kelheim; *Eurysternum*, from Solenhofen, and *Tretosternon*, from the Purbeck stage of the wealden. We know extinct species of *Emys* from the Kimmeridge clay of Soleure in France, and from the wealden of England and Germany. Five species of the same genus are found in the eocene stage of Sheppey. Fossil species of *Platemys* are found in the Kimmeridge stage of England and Switzerland. Two species have been obtained from the eocene stage of Sheppey, and from the tertiary beds of the same age in France and Belgium. Species of *Chelydra* and *Clemmys* are found in the upper tertiaries of the continent of Europe.

3rd Family.—The TRIONYXIDÆ, or fluviatile tortoises, have the body flat, the carapace and the plastron large, much depressed, and united by cartilage, deprived of horny plates, and covered with a soft integument. The plastron is incompletely ossified, and the original cartilaginous state of the margin of the carapace is persistent through life. The feet have five toes, of which three only have nails; hence the name, *trionyx*. The two unarmed toes support a webbed membrane for swimming. All the living Trionyxidæ are

* Sir W. Jardine, Rep. Brit. Association, refers these foot-marks to two genera, *Chelichnus* and *Herpetichnus*. See the beautiful illuminated plates in his "Ichnology of Annandale."

found only in the streams, rivers, and great fresh-water lakes of the warmer regions of the earth.

Very fine specimens of the fossil species of this family, nine in number, have been found in the lacustrine eocene sand of Hordwell, the fresh-water limestone of the Isle of Wight, the clay of Sheppey, and the sands of Bracklesham. For an admirable description and exquisite figures of these *Trionyces*, the student is referred to the monograph by Professors Bell and Owen.* The Hordwell specimens are in the cabinet of the Marchioness of Hastings. The annexed figures are from specimens obtained from the fresh-water limestone of the Isle of Wight.†

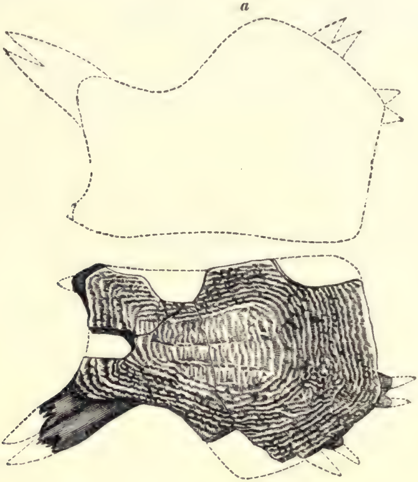


Fig. 197.—Sternal Plate of Fresh-water Turtle, from Binstead. (One-third linear the natural size.) The outline, *a*, represents the corresponding portion of the plastron.

4th Family.—The Chelonidæ, or marine turtles, have the carapace cordiform and depressed like an elliptical arch,

* Palæontographical Society.
† Dr. Mantell's Isle of Wight.

the extremities flattened, and enveloped in a horny integument, to form oars for swimming. The anterior pair are nearly double the length of the posterior pair. (Fig. 196.)

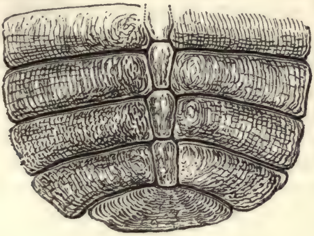


FIG. 198.—Portion of the Carapace of a Fossil Turtle, from St. Helen's. (Size of the original carapace sixteen inches long, and nine wide.)

The head is proportionally large, and cannot be retracted within the carapace: as a compensation, it is protected by an accessory bony shield, formed by an exogenous growth from the frontals, parietals, post-frontals, and mastoids, and not by the introduction of any new bones into the architecture of the cranium. The remains of this family have been found in the muschelkalk, in the wealden, the lower stage of the cretaceous period at Glaris, and the upper stage of the same formation at Maëstricht. In the marine eocene tertiary beds of Sheppey, Bracklesham, Bognor, and Harwich, are found perfect skulls, carapaces, and plastrons of chelone.* Eleven species are described and figured in the valuable monograph referred to; it is a remarkable fact that the clays of the Isle of Sheppey contain a greater number of species of *Chelone* than are known to exist in our modern seas. Zoologists know five species of existing *Chelone*, and only two of these, *Chel. midas*, and *Chel. caouanna*, frequent the same locality. "It is obvious, therefore," says Professor Owen, "that the ancient ocean of the eocene epoch was much less sparingly inhabited by turtles, and that these presented a greater variety of specific modifications than are known in the seas of the warmer latitudes of the present day.

* Pictorial Atlas, plate lxix.

"The indications which the English eocene turtles, in conjunction with other organic remains from the same formation, afford of the warmer climate of the latitude in which they lived, as compared with that which prevails there in the present day, accord with those which all the organic remains of the oldest tertiary deposits have hitherto yielded in reference to this interesting point."*

Second Order.—SAURIA. May be regarded as the true type of the Reptilian Class. They have an elongated body, with four extremities, which are generally directed outwards. Their feet are well developed, and there are in general five toes armed with claws. The number of the spinal vertebræ varies much. The body of each bone in existing families is concave before, and convex behind; the ribs are always present, and are united to a sternum; they encircle the organs of the abdomen, as well as those of the chest. The shoulders are

FIG. 199.—The Crocodile of the Nile. (Crocodilus vulgaris.)

formed of three pairs of bones, the *scapulæ*, the *clavicles*, and the *coracoids*, articulated together to form an arch, which sur-

* Palæontographical Monograph, page 44.

rounds the anterior part of the chest, and forms sockets for lodging the round head of the arm-bones, the *humeri*. The pelvic arch is in like manner formed of three pairs of bones articulated to the spine by two vertebræ: the tail is more or less developed. The Saurians are distinguished from Tortoises, by the absence of a carapace; from Serpents, by the possession of four extremities, moveable eyelids, and fixed jaws; and from Batrachians, by their scaly skin, and the absence of the metamorphosis through which that order passes in early life. A great number of fossil genera referable to extinct families have been found. Some of these present modifications of the bony skeleton which are quite unique. The Saurians of the secondary period depart most from living forms, and those which belong to existing genera are inhumed in the tertiary strata.

1st Family.—The Crocodilidæ, represented by the crocodile of the Nile, (Fig. 199,) includes several extinct genera. The form of the articulating surfaces of the bodies of the vertebræ enables us to subdivide them into those which have the vertebræ *concavo-convex*, *bi-concave*, and *convexo-concave*. To the first—the *concavo-convex*, which have the body of the vertebræ concave before and convex behind—belong the existing genera *Crocodilus* and *Alligator*. We find several species of fossil crocodiles in the tertiary strata of Europe, Asia, and America. Fine skulls and other parts of the skeleton of fossil crocodiles and alligators have been obtained from the crocodile bed at Hordwell. The tribe with *bi-concave vertebræ* is formed of extinct genera which lived during the secondary epoch. Here we group the *Teleosaurus*, which had the muzzle and the skull of the gavial. *Ælodon*, *Mystriosaurus*, *Macrospondylus*, *Gnathosaurus*, *Rachæosaurus*, *Pleurosaurus*, *Steneosaurus*, *Pelagosaurus*, are all found in the different stages of the oolitic period. *Succhosaurus* and *Goniopholis* are from the wealden of England; *Phytosaurus*, the most ancient crocodile, is from the trias of Germany; and *Pæcilopleuron* is from the great oolite of Normandy.

The group with *convexo-concave* vertebræ are those which have an inverse disposition of the articulating surfaces of these bones to what exists in living types: to this group belong a species of *Streptospondylus*, from the Kimmeridge stage of Havre, and a second from the wealden of Kent.

The *Cetiosaurus* has the bones spongy like those of cetacea, with no medullary cavity in the long bones; this genus, it is conjectured, attained the size of our largest whales. Of the four species known, one is from the Portland stage, and the others are from the wealden of England.

2nd Family.—The MEGALOSAURINIDÆ. This family is formed of extinct reptiles, remarkable for their gigantic dimensions, and for possessing a combination of anatomical characters which are found in no living genus of this class, by which the reptilian type of structure is connected with the mammalian, and a transition established between the crocodiles and the lizards. They resemble the mammalia in the form and size of the bones of their extremities, in which a well-developed medullary cavity is excavated. Their feet were short and resembled those of the pachyderms. The sacrum was formed of five vertebræ soldered together as in mammals; whilst in all other reptiles, living and fossil, the sacrum is composed only of one or two bones. The teeth of some resembled those of crocodiles, whilst those of others were allied to lizards. This family comprises three genera.

FIG. 200. Tooth of Megalosaurus. From the Stonesfield Slate.

The *Megalosaurus* had a straight muzzle, flattened on the sides, like the dolphin of the Ganges. The teeth were compressed and sabre-shaped, and finely denticulated on the edges. (Fig. 200.) The mode by which they were fixed in the jaw is intermediate between the crocodiles and the lizards. They were attached to the external wall of the maxillary bones in distinct sockets; internal to the row in use were others in different stages of development, destined to replace those that were lost through decay or accident. This disposition of the teeth is analogous to the dentition of many existing lizards. The remains of this genus are found in the great oolite of England and Normandy, also in the three stages of the wealden in England.

The *Hylæosaurus* is from the wealden of Tilgate Forest.

The *Iguanodon* is allied to the Iguana by the form of the teeth: they are not fixed in distinct sockets, but are soldered

by one side of the fang to the internal surface of the jaws. The vertebral bones, and those of the extremities, prove that this genus attained gigantic dimensions. (Fig. 201.)

Fig. 201.
Left Femur of an Iguanodon. From Brook Bay.
(The original 40 inches in length.)

a, Upper trochanter; *b*, middle trochanter; *c*, inner; *d*, outer condyle; *e*, groove between the condyles.

The figure of the tooth shows the singular structure of the crown, and how it was worn down by attrition. The Iguanodon was terrestrial and herbivorous. (Fig. 202.)

3rd Family.—The Lacertinidæ is composed of numerous genera of living and extinct reptiles, which have the lizards for their type. The existing genera are small terrestrial animals, but the extinct genera were of colossal dimensions, and are supposed to have been marine. We refer to this family:—

The *Protorosaurus*, from the Permian stage of Tubingen.

The *Thecodontosaurus* and *Palæosaurus*, from the dolomitic conglomerate of Bristol.

The *Cladyodon*, from the Keüper of Warwickshire.

The *Mosasaurus*, from the chalk of Maëstricht, France, England, and North America.*

The *Geosaurus*, from the Oxford stage of Solenhofen.

The *Leiodon*, from the chalk of Norfolk.

The *Raphiosaurus*, from the chalk of Cambridge.

* Pictorial Atlas, plate lxx.

The *Rhynchosaurus*, from the new red-sandstone of Grinshill.

4th Family.—The ICHTHYOSAURIDÆ. This singular family is composed of large extinct marine reptiles, which had structural affinities with the modern cetacea, and by which a transition is made from the reptilian to the mammalian types of structure: it comprises several genera.

The *Ichthyosaurus** had the general contour of a dolphin, the head of a lizard, the teeth of a crocodile, the sternal arch of an ornithorhynchus, and the paddles of a whale. The sclerotic coat of the eye was encircled by a series of osseous plates like the sclerotic of tortoises, birds, and some saurians.† The extremities are shortened, and converted into oars, and consist of a number of small cubical bones arranged like a tesselated pavement, firmly tied together by ligaments, and enveloped in the common integument. Their flexible spines, powerful tails, and oar-like fins, rendered them admirably adapted for an aquatic life, and the form and structure of their teeth show that they were carnivorous. Their intestinal canal was short, like that of some fishes, and was furnished with a spiral valve. We form this conclusion from the impression observed on the surface of the coprolites, which we find enclosed in their bodies, and strewed among the strata with their remains. We know one species from the muschelkalk of Luneville, in Germany. This genus attained its greatest development in the lias. The different stages of the oolites contain their remains, and they have been found in strata of the same age in North America.

FIG. 202.

Tooth of an Iguanodon. From the Wealden, Brook Bay, I. of W.

The *Plesiosaurus* had the head of a lizard, the teeth of a crocodile, a neck of enormous length like the

* See the frontispiece for restored figure of this reptile.

† Dr. Wright, on the Comparative Anatomy of the Organs of Vision, Cheltenham Magazine, 1837.

body of a serpent, the trunk and tail of a quadruped, the ribs of a chameleon, and the extremities of a whale. The

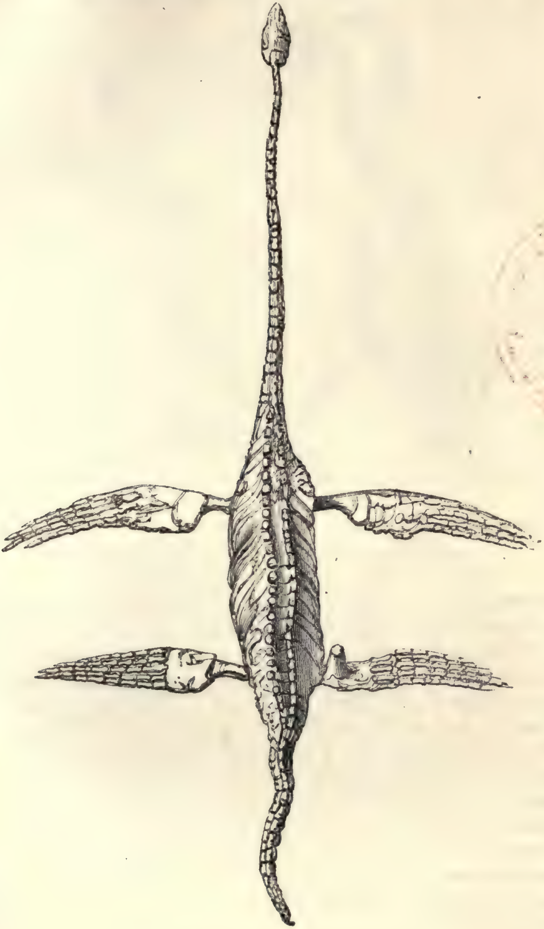


FIG. 203.—Plesiosaurus grandipinnis

plesiosaur has been likened to the body of a serpent concealed in the carapace of a turtle: the neck had thirty-three

Fig. 204.—Pterodactylus crassirostris. Goldfuss.

vertebræ, whilst in other genera of this class the numbers vary from three to eight. It probably lived in still water, not far from the shore. The first species is found in the trias, but their greatest development was during the deposition of the lias. They are found in the other stages of the oolite, and in the chalk of New Jersey, U. S. (Fig. 203.)

The *Pliosaurus* was a gigantic reptile, intermediate between the two preceding genera. We know two species from the Oxford and Kimmeridge clays.

Seven species of *Nothosaurus* have been found in the Devonian, Permian, and conchylian stages. *Diacosaurus*, *Conchiosaurus*, *Simosaurus*, and *Pistosaurus*, are from the muschelkalk of Germany; and *Spondylosaurus* is from the oolite of Moscow.

5th Family.—The Pterodactylidæ. If the Ichthyo-

sauridæ were remarkable for a combination of reptilian with cetacean types of structure, the Pterodactylidæ are no less so, for the singular affinities they establish between birds, bats, and lizards. It includes but one genus, *Pterodactylus.** In the length of the neck, and in the form of the head, it resembles a bird. (Fig. 204.) The trunk and the tail are like a quadruped. The numerous conical recurved teeth are formed after the Saurian type. The anterior extremities are constructed after the character of bats; the radical finger having been greatly elongated, and adapted for supporting a membranous wing, by which these ancient reptiles were enabled to soar through the air. We know seventeen species of this remarkable genus; one from the lias; one from the great oolite; fourteen from the Oxford stage of Solenhofen; and one from the wealden.

6th Family.—The LABYRINTHODONTIDÆ. Had the surface of the cranial bones wrinkled. The structure of the skull of this family is intermediate between the Saurians and the Batrachians. The form of their jaws, with their large teeth implanted in sockets, establish an evident analogy between them and the Ichthyosauridæ; whilst some anatomical points in the osteology of the skull appear to connect them with the

FIG. 205.—Python tigris.

* See frontispiece.

Batrachians. Their teeth are conical, slightly curved, and striated on the surface. Their microscopic character is remarkable for the labyrinth-like arrangement of the dentine, from whence Professor Owen derived the name Labyrinthodon. The microscope has not, however, solved the true position of the family; for their dental structure is equally removed from the crocodiles and the frogs. The sinuous windings of the plates of dentine, seen in the transverse section of the teeth, remind us of the structure observed in some fishes; but the circumstance of the teeth having been found in sockets in the jaw prevents any misconception as to the class to which they belong. We know five species of Labyrinthodon from the lower stage of the new red-sandstone of England.

The genera *Mastodonsaurus*, *Capitosaurus*, and *Metopias*, are from the Keüper, of Germany. It is conjectured that the foot-marks described as belonging to the genus *Cheirotherium*, by Kaup, were imprinted by the genera of this family.

Third Order.—OPHIDIA. Are characterised by their greatly developed vertebral column, articulated by ball-and-socket joints which give much mobility to the spine, by their numerous ribs, loosely united cranial bones, and absence of a sternum and extremities. (Fig. 205.) Ophidian remains are

FIG. 206.

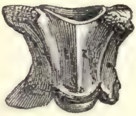


FIG. 207.

rare in a fossil state. An extinct genus *Palæophis* has been found in the clay of Sheppey, and vertebræ (fig. 206 and 207), probably belonging to the same, were found in the sands of Bracklesham, and in the eocene sand of Kyson, in Suffolk. The eocene stage of Brussels contains a fossil species of *Crotalus;* and a species of *Coluber* and of *Ophis* are found in the sub-apennine stages of Europe. These Ophidian remains confirm the inference already drawn from the presence of tropical genera of Mollusca, Chelonia, and Sauria, in the eocene ter-

tiary strata of our island, that the temperature of the north of Europe, during the tertiary epoch, was warmer than in our day. The physiological reasons already stated, in our general remarks on the class, prove that it would be impossible for serpents of the size of *Palæophis* to live in the present climate of the south of England.

Fourth Order.—BATRACHIA. Form a well-defined group of reptiles. On their escape from the egg, they present an organisation which resembles fishes. They breathe by gills; lead an aquatic life; and soon pass through a series of changes, by which they lose the gills, acquire feet and lungs, and are metamorphosed into perfect Batrachia, of which the frog and salamander are types. In addition to this physiological character, their skeleton differs from other reptiles. The skull is flat; the teeth, when they exist, are small, sharp, and nearly equal throughout; the ribs are absent, or are

FIG. 208.—Rana temporaria.

merely rudimentary. We divide the order into two families, characterised by the presence or the absence of a tail.

1st Family.—The Ranidæ. Composed of those which, like the frog, have no tail in adult life. To this group belong the *Palæobatrachus*, from the sub-apennine stage near Bonn; *Palæophrynos* and *Palæophilus* are from the sub-apennine of Œningen; to the existing genus *Rana* we refer some extinct species from the falunian and the sub-apennine stages of Weisenau.

2nd Family.—The Salamandridæ. Formed of the genera provided with a tail. To this group belongs the famous fossil skeleton from the sub-apennine of Œningen, which Scheuchtzer mistook for a human skeleton, and described under the name *Homo diluvii testis*. The Baron Cuvier detected and exposed this error. He demonstrated, beyond all doubt, that the bones belonged to an extinct salamander, *Andrias Scheuchtzeri* (fig. 209), the length of which was nearly five feet. Fossil species of the existing genus *Salamandra* are found, with fossil *Rana*, in the falunian, and the sub-apennine stages of Sansan.

In reviewing the history of fossil reptiles, we find that they have obeyed a law of distribution nearly allied to that which we have already described in the history of fossil fishes. They were created towards the close of the palæozoic epoch, and lived in the subsequent periods of the earth's eventful history.

Reptiles do not exhibit any growing progression in their typical forms; for the genera which lived in the past ages, and have left their remains in the earth's layers, are three times more numerous than those which exist at the present time.

The study of these remains shows that there has been a successive replacing of animal forms, some of which were ephemeral, others were more persistent, whilst in all there has been many singular departures from the typical structure of reptiles among the ancient forms, when compared with the living representatives of the class.

The Saurians, which are the most highly organised order, were created towards the close of the palæozoic epoch: the *Protorosaurus*, from the Permian strata of Thuringia, attests this fact. They increased in generic forms in the triasic, and had their maximum development in the oolitic and wealden

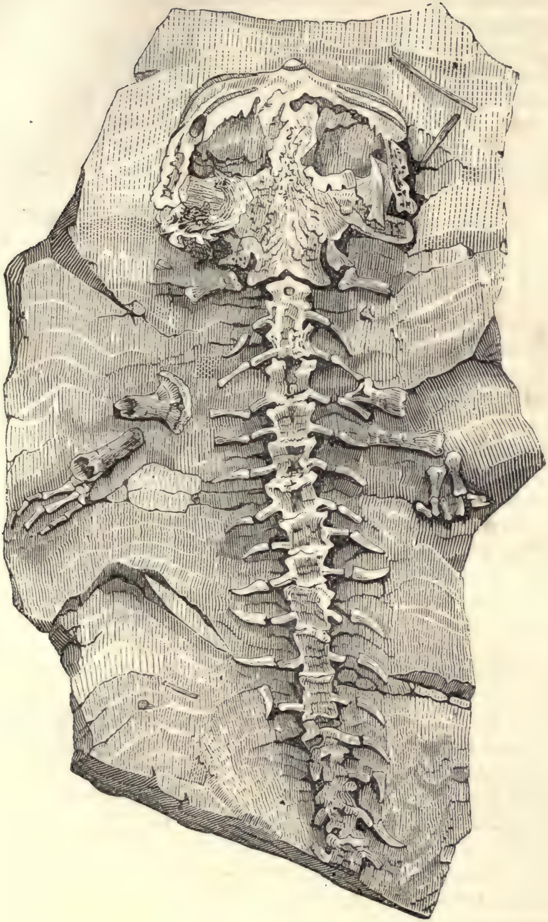


FIG. 209.—Andrias Scheuchtzeri.

periods: their numbers became greatly diminished in the cretaceous stages; and in the tertiary strata we find the remains of only crocodiles and alligators.

The saurians exhibit, therefore, an order of decadence from the oolitic period down to the present; for we cannot for a moment compare the Crocodiles, Manatis, Iguanas, and Lizards, of our day, with the enormous reptiles that basked on the shores, and swam in the waters,—that trod the earth, and flitted through the air, during the oolitic and wealden periods.

We have seen that the Saurians form six families; of these, four are now entirely extinct, and two only are living —the Crocodilidæ and the Lacertinidæ.

Of the extinct families, the Megalosauridæ lived along the shores of ancient rivers, from the great oolite to the neocomian stages.

The Labyrinthidæ were gigantic frog-like reptiles of like littoral habits, and were special to the triasic period. They have left their huge foot-marks on the muddy shores, and their bones in the Keüper strata of that period.

The Ichthyosauridæ were organised solely for an aquatic life: they ranged from the triasic to the oolitic periods, but had their greatest development in the lias.

The Pterodactylidæ differed from all other families either living or extinct in the structure of their anterior extremities, which were at once feet and wings, and fitted these reptiles for leading an arboreal life in the forests of the ancient land. They extended their range from the lias to the wealden stages, but were most abundant about the middle of the oolitic period.

The *Chelonians* left their foot-steps on the triasic strata, and have lived in all the subsequent periods. They attained their greatest development in the modern epoch.

The *Ophidians* and the *Batrachians* were created during the tertiary period, so that in reptiles and fishes, the orders the most inferior in organisation were the last created of their class. Whilst the saurians exhibit a decadence, the ophidians and batrachians show a great increase of forms in the modern epoch.

The theory of progressive development receives no support from the facts unfolded by the history of fossil reptiles.

The genera that were first created, belonged to the most highly organised types of the class, whilst those which exhibit a persistent form of some of the stages of embryonic life, as the frogs and salamanders, did not appear until the tertiary period. This fact, it will be remembered, exactly accords with what has been observed in the stratigraphical distribution of fossil fishes.

Class III.—BIRDS.

The class of birds is one of the most natural and best defined in the animal series; whether we take their external form and covering, or their internal organisation and physiological peculiarities, as the basis of a definition.

They are vertebrated animals, with warm blood, and a double and complete circulation. They breathe the elastic air, not only by lungs, but that life-giving fluid penetrates abdominal air sacs, and even the bones themselves. The anterior extremities are organised to form wings; the body is covered with feathers, and they are oviparous.

Birds may be said to be to the vertebrated, what insects are to the invertebrated classes. The structure of the skeleton is very characteristic; the bones are more compact, white, dense, and brittle than those of mammalia, reptiles, and fishes. They have thinner parietes, and their internal cavities are proportionally larger, and they for the most part contain air instead of marrow.

Ossification proceeds to a greater extent in this than in either of the other classes, consequently many bones which remain separate through life in mammals and reptiles are soldered together in birds. The typical form of the skeleton is well preserved in all the different orders of this class. The anterior extremities are adapted solely for flight, the legs for support, and the head and neck are long and extensively moveable for prehension. The trunk is fixed and solid, to afford a firm surface for the attachment of the muscles concerned in locomotion. The vertebræ of the neck and tail are nearly the only bones of the spinal column that are

moveable on each other. The shoulder arch is formed of two clavicles united together at their lower ends, to form a V-shaped bone, known as the merry-thought, two long blade-shaped scapulæ, and two strong coracoids. These six bones are firmly tied together with ligaments. The coracoids are articulated to the sternum, and resist the too near approximation of the arm bones to the median line in the down stroke which the wing makes in the act of flying. The sternum is a broad plate of bone which covers the greater part of the inferior surface of the body, as in Chelonia. It has, in general, a median elevated crest, destined to give a more extensive attachment to the pectoral muscles. The pelvis is formed of three bones on each side, as in reptiles and mammals, but in birds they are soldered together into a single piece, which extends forwards and backwards from the cavity of the hip-joint along the sides of the sacrum as in saurian reptiles.

In the anterior extremities we find an arm-bone; two bones in the fore-arm, and carpal, meta-carpal and phalangeal bones. In the posterior extremities is a thigh bone, two leg bones, a tarsus, and a meta-tarsus, formed of a single bone, which presents three pulley-like surfaces on its lower end, for the attachment of the three toes which are directed forwards, and one for the small toe or thumb which is directed backwards. The number of joints increases in each toe, commencing with the thumb, which has two, the second toe three, the third toe four, and the fourth toe, which has five phalanges.

The skull is small and is composed of thin, compact bones firmly united together. The orbits are large; the upper jaws are greatly developed by the elongation of the bones of the face, and the lower jaw is articulated to a tympanic bone as in reptiles.

The jaws are covered with a horny coating, as in Chelonia, and are adapted as organs of prehension. The uniformity of the typical character of the skeleton, renders the osteology alone an imperfect means for determining the orders of this class. The bill and the feet, so important to the zoologist, are unfortunately not often preserved in a fossil state. For these reasons, our knowledge of fossil birds is much behind that of the other classes of the vertebrata.

Professor Hitchcock refers to birds, the fossil foot-marks discovered in the new red-sandstone of Massachussets. The imprints succeed each other regularly, and are of gigantic dimensions, being fifteen inches long, and ten inches broad, and from four to five feet apart, indicating the immense stride of the animal. No bones of birds have been found in these imprinted strata, and it is yet doubtful whether they belonged to birds or to some other unknown animal.

1st Order.—RAPTORES (Birds of prey, fig. 210). To this group is referred the extinct genus *Lithornis*, found in the eocene stage of Sheppey. Fossil species of *Haliætus*, (fig. 210), *Buteo*, and *Strix* are found at Montmartre. Species of *Catarthes* in the sub-apennine stage of Auvergne, and
tar- of *Vultur* and *Aquila* in diluvium.

2nd Order.—INCESSORES (or Perchers, fig. 211.). To this IN
order belongs the extinct genus *Protornis*, from the schists of Glarus. We know extinct species of the existing genera, *Turdus* (fig. 211), *Fringilla*, and *Corvus*, from the falunian stage of Sansan; and the remains of *Motacilla*, *Anabates*, *Hirundo*, and *Caprimulgus* are found in the diluvium of caverns.

FIG. 210.—Haliætus leucocephalus.

3rd Order.—SCANSORES or (Climbers, fig. 212). To this order belongs the extinct genus *Halcyornis* from the eocene of Sheppey, and *Coccyzus*, *Picus* (fig. 212), and *Psittacus* from the osseous caverns of Brazil.

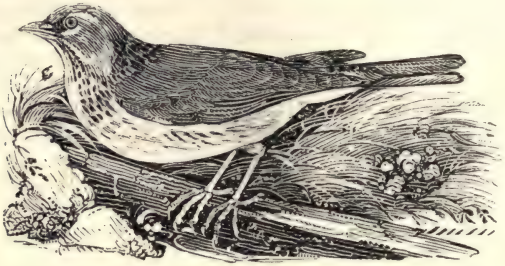


FIG. 211.—Turdus iliacus.

4th Order.—RASORES (or Scratchers, fig. 213). All the fossil species of this order belong to existing genera, *Perdix*, from the eocene of Montmartre; *Phasianus*, *Gallus*, *Numida* (fig. 213), *Crypturus* from osseous caverns.

FIG. 212.—Picus viridis.

5th Order—CURSORES (or Runners, fig. 214). To this group belongs the new genus *Dinornis*, whose remains have been found in such abundance in the diluvium of New

Zealand, remarkable for the colossal dimensions of its skele-

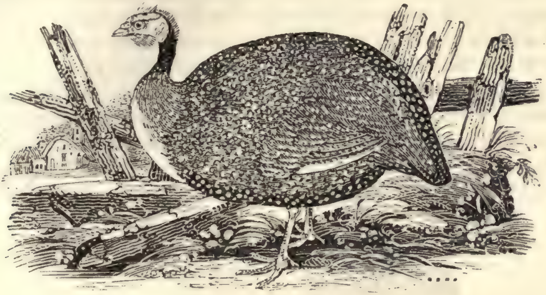


FIG. 213.—Numida meleagris.

ton, part of which is now in the Hunterian Museum of the College of Surgeons. We know five species; one was

FIG. 214.—Casuarius galeatus

upwards of twelve feet in height. Its *femur* (thigh-bone) measures fourteen inches in length, and seven in circumference. The *tibia* (leg-bone) twenty-eight inches and a half. This gigantic bird was intermediate in structure between the cassowary (fig. 214) and the apteryx.

In the caverns of Brazil are found an extinct species of *Rhea*, of which the genus still lives on that continent. Cursores with a compressed beak are represented by an extinct genus, the *Dodo* (fig. 215). This bird is known from a description given by one of the early Dutch navigators. A foot of this

FIG. 215.—Didus ineptus.

remarkable genus is preserved in the British Museum, and a head in the Ashmolean Collection at Oxford. It has, therefore, become extinct during the human epoch.*

6th Order.—GRALLATORES (or Waders). An extinct genus, *Palæornis*, has been found fossil in the wealden of Kent. A species of *Scolopax* in the chalk of Jersey, U.S.; *Tantalus*, *Scolopax*, *Numenius*, and *Fulua* in the eocene of Montmartre; *Ciconia* and *Scolopax* in the falunian of Wiesbaden and Wiesenau.

Bones of *Phœnicopterus* are found at Auvergne, and those

* For further details on the Dodo, the student is referred to the beautiful monograph by Dr. Melville and Mr. Strickland.

of *Olis*, *Rallus*, and *Crex*, in diluvian deposits with the preceding genera.

7th Order.—NATATORES (or Swimmers). To this group belong the extinct genus *Cimoliornis*, from the wealden of Kent, and the extinct species of *Carbo*, from the eocene of Montmartre. The same genus with *Mergus* and *Anos* are Au found in the sub-apennine of Auvergne; and *Larus*, *Anser*, and *Colymbus*, in the diluvium of caverns.

Class IV.—MAMMALIA.

This class includes man, and all the higher quadrupeds that nourish their offspring during the first months of their life with a nutritious secretion or milk, furnished by two or more mammæ, or milk glands. Their skeleton presents important modifications of structure, which serve for the distribution of the class into many natural orders.

The skull is composed of three vertebræ, the elements of which are greatly developed and expanded to form the cranium. The first is the *occipital;* the second the *sphenoid* with the two *parietal;* the third the *ethmoid* with the two *frontal.* The face is formed of the two upper *maxillary*, and two *inter-maxillary*, two *palate*, and two *nasal* bones, &c., &c. The six first bones form the upper jaw. The lower jaw is formed of two branches united at the median line, and articulated by two condyles to the glenoid cavities of the temporal bones, without any intermediate tympanic bones, as in the oviparous vertebrata.

The spinal vertebræ are divided into *cervical*, *dorsal*, *lumbar*, *sacral*, and *caudal*, as they are situated in the neck, back, loins, sacrum or tail. The neck is always formed of seven vertebræ; the number in all the other regions varies much. The number of those in the dorsal region corresponds with the number of the ribs. These bones are united before to a sternum, formed of a series of small bones, disposed in a line and united end to end. The anterior extremities are formed of *scapulæ*, or blade-bones, suspended by muscles alone or connected with the sternum by *clavicles*, or collar-bones.

The presence of a clavicle is always associated with certain uses of the anterior extremity; thus monkeys, rodents, and carnivora possess this bone in common with man, but it is absent in ruminants and pachyderms. The arm is formed of a single bone, the *humerus;* the fore-arm of two bones, the *radius* and *ulna;* the hand is formed of two ranges of bones, the *carpal* and *meta-carpal*, and the *phalanges* of the fingers; the thumb has two *phalanges*, and the other fingers three. The posterior extremities (the cetacea excepted, in which they are absent) are attached to the spinal column by a bony arch, or pelvis, formed of three pairs of bones, *ilia*, *ischia*, and *pubes*, which are separate in early life, but are firmly soldered together in adult age. The thigh, like the arm, consists of a single bone, the *femur;* the leg, like the fore-arm, of two bones, the *tibia* and the *fibula;* the foot, like the hand, of three ranges of bones, *tarsal*, *meta-tarsal*, and *phalanges*.

The jaws are for the most part armed with teeth, which present great varieties as to form, structure, and arrangement in the different orders; the teeth are very dense in this class, and are the parts of the skeleton which resist destruction longest; they are consequently the best preserved: the palæontologist, therefore, studies their form and microscopic structure with great attention, as the teeth often remain in a high state of preservation after the bones have been decomposed or water-worn. Some mammals are preserved entire by the antiseptic power of ice, as the rhinoceros and elephant of Siberia, in which even the muscles and the ligaments, integument and hair, were preserved.

We arrange the class into two divisions:—the DIDELPHIA and the MONODELPHIA.

The DIDELPHIA, by a certain organic disposition, are born in an immature state at an early period of their development, and require special organs for their preservation, consisting of a pouch in the abdomen of the mother, in which are situated the nipples of the milk glands. The young adhere to these organs during the first period of their pouch-life, and never quit the mammæ until their development has advanced. The didelphia have special bones, called marsupial, for supporting the pouch. The kangaroos, and other Australian animals, belong to this class.

The MONODELPHIA, comprehend the great majority of the mammalia. In this group the young have attained, at birth, their full development, and require only the care of the mother and the nourishment of her milk; they have neither a marsupium nor marsupial bones.

MAMMALIA DIDELPHIA

Have an organisation inferior to that of the monodelphians: their brain, dental system, and skeleton, afford proofs of an organic inferiority. If the few facts we possess relative to the jaws found in the Stonesfield slate at the base of the great oolite are confirmed by subsequent observers, then the creation of this sub-class must have long preceded that of the higher mammals. The Stonesfield fossils have been referred by Professor Grant of London, and the late Professor De Blainville of Paris, to reptiles; and by MM. Valenciennes and Dumeril in France, and Professor Owen of London, to mammifera.* The anatomical evidence is in favour of the latter opinion.

These jaws are referred to two genera, *Thylacotherium*, which has numerous small bifanged molar teeth, of which the annexed wood-cut will convey a good idea. Two species of this genus have been found at Stonesfield.

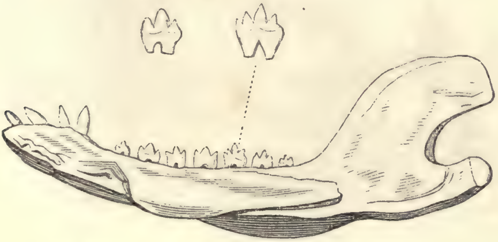


FIG. 216.—Jaw of the Thylacotherium from Stonesfield.

* Mr. Waterhouse, of the British Museum, whose profound knowledge of the Mammalia entitles his opinion to the highest consideration, has no doubt as to the Mammalian character of these jaws. The specimens which he kindly showed us, exhibit the mammalian characters in a marked degree.

Phascolotherium has four true, and three false, molars. Of this genus only one species is known. Two extinct species of *Didelphis*, all the living species of which are limited to America, are found in the eocene of Montmartre, at Kyson in Suffolk, and in the caverns of Brazil. Species of *Dasyurus*, *Thylacinus*, *Halmaturus*, *Hypsiprimnus*, are found in the caverns of New Holland.

m

MAMMALIA MONADELPHIA.

The organs of locomotion, of touch, and of mastication afford characters for the sub-division of the monodelphians into the following orders:—

1st Order.—CETACEA. Resemble fishes in their external contour; the anterior extremities are shortened and en-

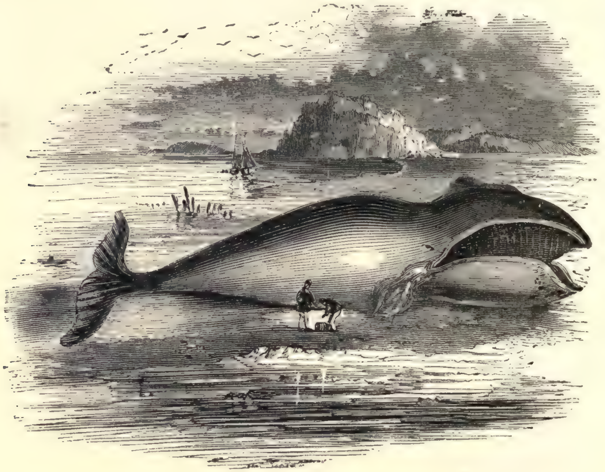


FIG. 217.—Balæna mysticitos.

veloped in skin to form fins, but in the frame-work of these organs we find the representative bones of the arm and hand

of other mammals. The posterior extremities are absent, and the body terminates in a broad horizontal fin. (Fig. 217.) The bodies of the cervical vertebræ are much flattened, and the portion of the temporal bone, which contains the internal ear, is united to the temporal by ligaments.

This order contains three families.

The BALÆNIDÆ (or Whales) have an enormous head; the jaws are provided with horny laminæ, instead of teeth. Three species of *Balænoptera* are found in the sub-apennine stage of Italy, and one of *Balæna* from the same stage of Piedmont and the United States. Two species are found in the pleistocene of Herne Bay, and the diluvium of England.

The DELPHINIDÆ (or Dolphins) have the head small, and the jaws provided with numerous sharp conical teeth (fig. 218.) We know two extinct genera of this family, *Ziphius*, from the eocene of Provence, and *Balænodon*, from the same stage in England. From the upper tertiary beds of France, England, and America, species of *Delphinus*, *Monodon*, and *Physeter* have been obtained.

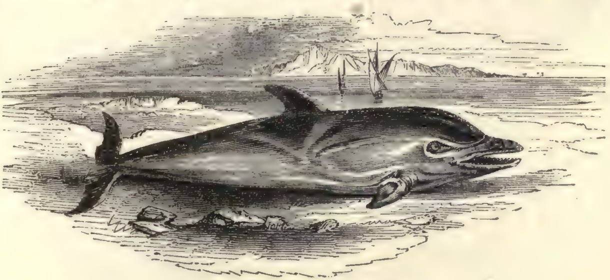


FIG. 218.—Delphinus delphis.

The MANATIDÆ (or herbivorous whales) have molar teeth with flat crowns. They frequent the mouths of the great rivers in the tropical regions of the Old and New Worlds. The Dugong (*Halicora*) and the Lamantin (*Manatus*) are its living types. We find fossil species of these genera in the newer tertiaries of Switzerland and of North America. This family contains several extinct genera, as *Metaxytherium*, of which an entire skeleton was found at Beaucaire, and different portions in the falunian stage of Touraine.

Zeuglodon, at first described as a reptile under the name *Basilosaurus*, was shown, from the miscroscopic structure and mode of implantation of the teeth, to be a cetacean. We know one species from the eocene stage of Alabama, U. S.

Dinotherium had a large head, with a flat occipital bone, and large nasal fossa, opening upwards; arched nasal bones, and large holes for the passage of the fifth pair of nerves; hence it is inferred that the animal possessed a proboscis. The lower jaw had two enormous teeth that curved downwards (fig. 220). The molars are $\frac{5}{5}$, and are allied to the tapirs and the lamantins (fig. 219). This singular animal was supposed to be a quadruped, and was restored by Kaup, as shown in the annexed figure (fig. 220). The true relation of this extinct genus is not yet determined. The flatness of the occiput, the high position of the condyles, the absence of crests for the attachment of ligaments to carry so large and so massive a skull, the down-curved tusks of the lower jaw, like those of the young lamantin, together with the form of the ocular and temporal fossæ, and the form of the molars, led De Blainville to the supposition that it was a cetacean, whilst Kaup and Owen consider

FIG. 217.
Tooth of Dinotherium.

FIG. 220.—The Dinotherium.

it a pachyderm, allied to the tapir and mastodon. A perfect skull was found at Eppelsheim, and less perfect specimens have been detected in the miocene stages of France, Germany, and Switzerland. This remarkable genus lived for a limited time; it was created about the middle of the tertiary period, and became extinct towards its close. The remains of three species are found in the middle and upper tertiaries of France, and in the upper tertiaries of Germany and Switzerland.

2nd Order.—RUMINANTIA. They all subject their food to a complicated process of digestion, and have a compound stomach, with four compartments, for that purpose. They have no incisor teeth in the upper jaw, but only a callous pad instead thereof. Their feet are provided with hoofs. The frontal bone is often armed with horns, which are sometimes supported upon a bony axis. The lower jaw has from six to eight incisors. Some have canine teeth, in others they are absent. They have always $\frac{6\cdot6}{6\cdot6}$ molars; the crowns are marked with double crescents, the convexity of

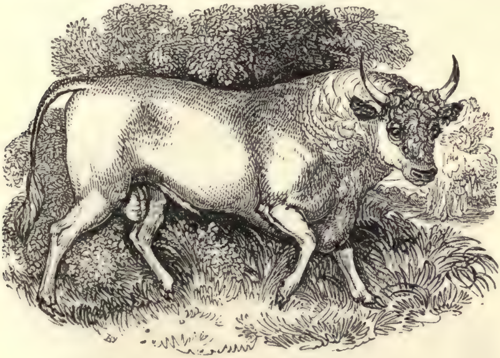


FIG. 221.—Bos scoticus.

which is directed inwards in the molars of the upper, and outwards in those of the lower jaw. The feet are terminated with two toes; the metacarpal and the metatarsal bones are soldered, to form a single *canon* bone. The toes are enveloped in two hoofs, and sometimes there are vestiges

of rudimentary toes, that project backwards; in all the ruminants, with the exception of the Camels and Llama, the The foot is bisulcate.

1st Family.—The Bovidæ (or the oxen, fig. 221) have persistent horns, with an osseous axis covered with a sheath of true horn. The caverns of Brazil contain the extinct genus *Leptotherium*. In the sub-apennine stage of Europe, Asia, and North America, fossil species of the existing genus *Bos* are found. *Antilope* was discovered in the miocene stage of Eppelsheim and Sansan, and, together with *Capra*, in that which preceded the modern epoch.

2nd Family.—The Cervidæ (or the stags, fig. 222) have caducous antlers, destitute of a horny sheath. This family contains several extinct genera, and many fossil species of living genera.

The *Sivatherium* formed a connecting link between the ruminants and the pachyderms. The head was armed with horns, and from the inflated arched form of the nasal bones, it is conjectured that it had a proboscis like the elephant. The horns were four in number. Two arose from the frontal bone, between the orbits, and branched outwards; and two others, probably shorter and more massive, arose

Fig. 222.—Cervus capreolus.

from the prominent eminences seen on the superior and posterior parts of the head. The skull nearly equalled in volume that of the elephant, and presented many points of analogy with it. The molar teeth, $\frac{6\text{-}6}{6\text{-}6}$, exhibit the ruminant type of structure. We know only one species, described by Cautley and Falconer, from the miocene stage of the Himalaya.

Two species of the *Dremotherium* are found in the sub-apennine stage of Auvergne, in France. A great many fossil species of the existing genus *Cervus*, are found in the falunian, sub-apennine, and diluvial stages of both continents. No less than eighteen species are found in the miocene of Eppelsheim and Sansan. One of the most remarkable was the *Cervus megaceros*, whose colossal horns had a span of more than three yards from point to point, and whose remains are found in the peat bogs of Ireland, the Isle of Man, and in a great part of Europe, and of which the annexed figure (223) will help to convey an idea. There is a

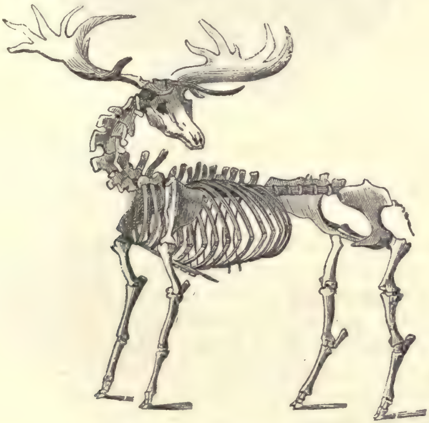


FIG. 223.—Cervus megaceros, Cuv.

perfect skeleton of this species in the museum of the Royal College of Surgeons, Edinburgh. A great number of bones belonging to stags and the reindeer are found in the caverns of Europe, and those of South America.

Moschus has two species in the miocene of Germany, and in the sub-apennine of Bengal.

Camelopardalis, which now only exists in Asia, has left remains of a smaller extinct species in the sub-apennine of France.

3rd Family.—The CAMELIDÆ depart from the typical form of ruminants in their dental formula, and in the

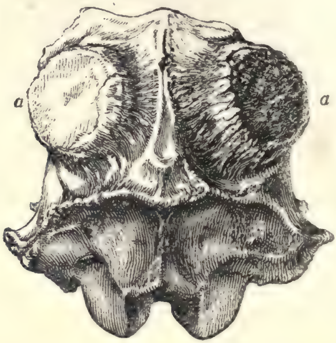


FIG. 224.—Fossil skull of a Rein-Deer, from a fissure in a quarry at Binstead, Isle Wight.*

a, a. The osseous bases to which the antlers were attached. (One-third linear of the natural size.)

structure of their feet. They have six incisors in the lower jaw, and two in the upper, two canines in each jaw, and from twenty to twenty-two molars, instead of twenty-four. The canon bones are more divided, and the feet are not so much sulcate. A fossil genus, *Mericotherium*, has been found in the glacial regions of Siberia. Fossil species of two existing genera, as *Auchenia*, have been found in South America, and *Camelus* in the sub-apennine stage of France, Asia, and South America.

3rd Order.—PACHYDERMATA. The families of this order played an important part in the tertiary period. The extinct genera are numerous and remarkable, and afford

* Mantell's Isle of Wight.

important links for uniting in a natural series the several groups of which it is composed. Their toes are enveloped in horny hoofs; they are all herbivorous; most of the genera are remarkable for the thickness of their skin, which gives value to the name Pachyderm. We divide it into three

FIG. 225.—Auchenia glama.

families—the solid-hoofed, the ordinary pachyderms, and the proboscidians.

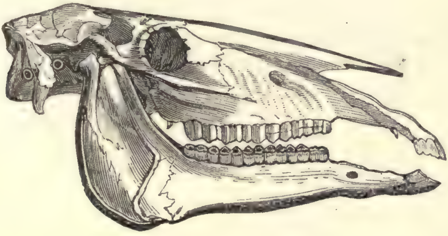


FIG. 226.—Skull of the horse.

1st Family.—The SOLIPEDÆ. The extremities have a single toe to each foot. The dental formula is, incisors, $\frac{6}{6}$,

canines $\frac{1\text{-}1}{1\text{-}1}$, molars $\frac{6\text{-}6}{6\text{-}6}$, the latter marked with five crescents, formed by concealed plates of enamel. (Fig. 236.) We know one extinct genus, *Hippotherium*, from the miocene stage at Eppelsheim. Fossil species of the genus *Equus* (fig. 226) have been found in the sub-apennine stage of Europe, Asia, and the Pampas, and in the caverns of South America. The horse was unknown in that continent before its conquest by the Spaniards.

2nd Family.—The Ordinary Pachydermata is composed of a group of extinct, and a group of existing genera. The extinct are *Chœropotamus*, which has molars $\frac{7\text{-}7}{6\text{-}6}$. Two species have been found in the eocene stage of Paris, and of the Isle of Wight; and three others in the falunian stage of France and Asia.

Hyracotherium, so named in consequence of its structural affinities in the size of the orbits, &c., with the *Hyrax*, was found in the London clay and the lacustrine eocene sand at Kyson.

Anthracotherium; molars $\frac{7\text{-}7}{7\text{-}7}$ allied to the hogs by the molars of the lower jaw, and to the *Anoplotherium* by the molars of the upper jaw; also to the tapirs, by the form of its canine teeth. Its name is derived from the locality where it was first found among the anthracite of Cadibona (near Savone, Piedmont); we know five species—three are eocene, and two belong to the miocene stage of Eppelsheim and Sansan.

Lophiodon is allied to the tapirs; its name is derived from the pointed eminences on its molar teeth. This genus is characteristic of the miocene stage: eleven species have been obtained in France and Germany. Some of the species are

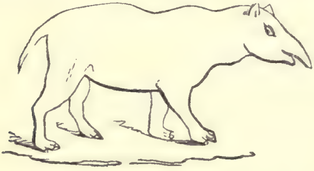


Fig. 227.

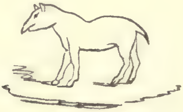


Fig. 228.

found in the eocene, but the great majority lived in the middle ages of the tertiary period.

Palæotherium had incisors $\frac{6}{6}$, canines $\frac{1}{1}$, and molars $\frac{7}{7}$. The canines are longer than the incisors. The superior molars are square, and the inferior molars have double crescents. The nasal bones formed an arch as in the tapirs; we know about eleven or twelve species—seven are found in the lacustrine eocene beds of Montmartre and the Isle of Wight. They are distinguished by their height, and by the proportional development of the extremities. *P. magnum* was the size of a horse (fig. 227), and *P. minimum* was not larger than a hare. (Fig. 228.) The other species are found in the lacustrine miocene beds of Sansan. It is probable that the genus contained many more species. Fig. 229 represents the lower jaw and teeth of *Palæotherium minus*, from the fresh-water limestone of Seafield, Isle of Wight.

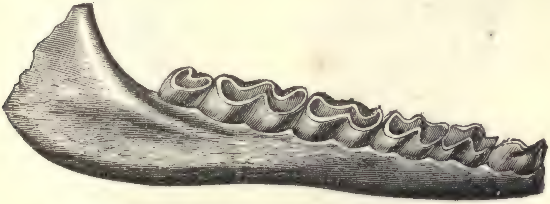


FIG. 229.—Lower Jaw of Palæotherium minus, Isle of Wight.

Anoplotherium had affinities with the rhinoceros, horse, hog, hippopotamus, and camel: (fig. 231) the anoplother had forty-four teeth, which formed a continued series without any

FIG. 230.

FIG 231.

interruption; a character found now only in man and the monkeys. We count $\frac{6}{6}$ incisors, $\frac{1\text{-}1}{1\text{-}1}$ canines, $\frac{7\text{-}7}{7\text{-}7}$ molars, of

which the anterior are compressed. The posterior molars in the upper jaw have square crowns, and those of the lower jaw have double crescents. The extremities had two toes developed like Ruminants; some species had, besides, rudimentary toes: the metacarpal and metatarsal bones remained separate, and did not form a single *canon* bone as in ruminants. Of the three species known, two, of the size of a hog, and of an ass, are from the lacustrine eocene stage of Montmartre and the Isle of Wight. The third is from the sub-apennine of Asia. The other extinct genera, *Potamohippus*, *Chærotherium*, *Elasmotherium*, are from the newer tertiary or sub-apennine stage. *Hyotherium*, *Macrauchenia*, *Chalicotherium*, are from the miocene stage.

Ziphodon and *Adapis* are from the lacustrine eocene stage, and *Toxodon* is from the newer tertiary of the Pampas of South America.

FIG. 232.—Hippopotamus amphibius.

Fossil species of *Sus* and *Tapirus* are found in the miocene stage of Eppelsheim, and *Dicotyles* in the caverns of Brazil.

Of the genus *Hippopotamus*, which now lives on the banks of the large rivers of Africa (fig. 232), the remains of fossil species have been found in the sub-apennine and alluvial stages of Europè, North America, and India. (Fig. 234.)

Of the genus *Rhinoceros*, we know ten species—four are found in the miocene stage at Eppelsheim and Sansan, the others in the sub-apennine and diluvium of Europe. (Fig. 233.) Some of the fossil species ranged into latitudes which are now constantly glacial regions, as the rhinoceros, with its skin entire, found by Pallas in 1781, in frozen drift, near

Fig. 233.—Rhinoceros, from fresh-water tertiary strata; molar, lower jaw.

Fig. 234.—Hippopotamus, molar, lower jaw.

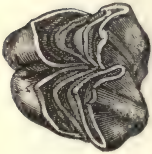


Fig. 235.—Recent Elk, grinding surface of molar, upper jaw.

Fig. 236.—Horse, from Brighton cliffs, second molar, lower jaw.

the Lena, at 64° North latitude. The diluvium and the caverns of England contain the remains of this genus.

3rd Family.—The ELEPHASIDÆ, or proboscidians, (fig. 241) have five toes to each foot, two long tusks which escape from the mouth and curve upwards, a long, muscular, and highly-

FIG. 237.—Rhinoceros Indicus.

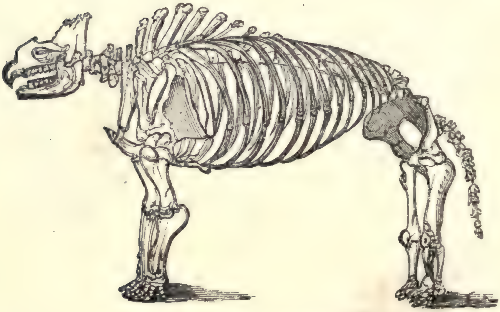


FIG 238.—The Mastodon giganteum

flexible proboscis, which reaches the ground and serves as a prehensile instrument; the genus *Elephas* is the only existing type of this family, but the discoveries of Cuvier have added the extinct genus, *Mastodon*, which resembled the elephant in its general form (fig. 238), but differed from it in

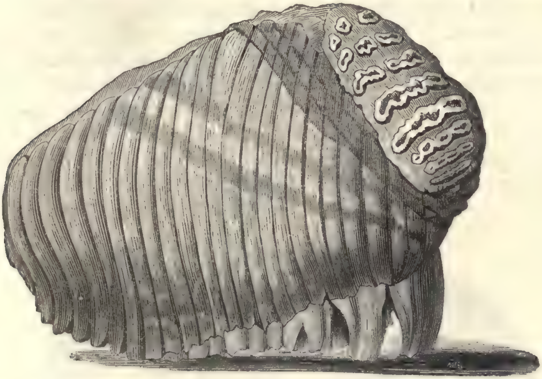


FIG. 239.—Elephas primigenius, or mammoth, from Brighton cliffs. Molar lower jaw, right side, one third of natural size.

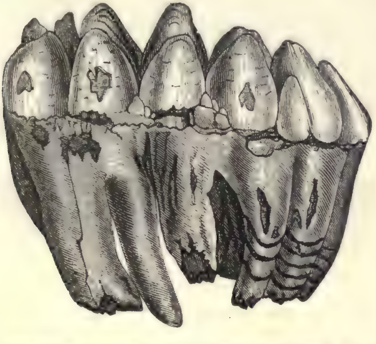


FIG. 240.—Mastodon ohioticus. Molar tooth, one-fourth of natural size.

the structure of its molar teeth, the crowns of which, as shown in fig. 240, presented a series of conical mammillated

eminences, instead of the flat grinding surface observed in the molars of the elephant. (Fig. 239.) In early life the mastodon had two small, straight, tusks, which projected from the lower jaw; this circumstance led Godman to propose the genus *Tetracaulodon*, for the remains of a young mastodon; as these lower defences are, however, deciduous, and only characterise the immature animal, the genus must be rejected. The palæontological gallery of the British Museum contains a noble specimen of the *Mastodon*. This genus included several species, two or three of which are well ascertained: the *M. giganteus* is found in the sub-apennine stage of North America, Europe, Asia, and New Holland; *M. angustidens* is found in the miocene stage of Eppelsheim and Sansan; *M. longirostris* from the same stage in Eng-

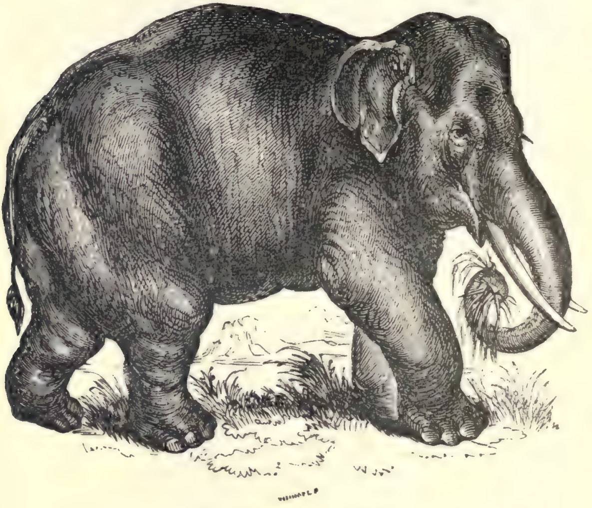
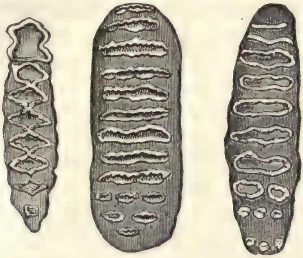


FIG. 241.—Elephas Indicus.

land, France, and Germany. The other species have been discovered in Europe, Asia, and America. A more accurate anatomical investigation, however, must be made of the

remains of those supposed new species, before we can admit the numbers that have been described; many of the species may be only varieties depending on sex and other causes.

The genus *Elephas* has the upper jaw armed with two enormous tusks (fig. 241), which are, in fact, greatly-



1 2 3

FIG. 242.—Teeth of Elephants. 1. *E. africanus*. 2. *E. indicus*. 3. *E. primigenius*.

developed incisor teeth, that grow upwards in a curved direction; the molars are one or two in number, in each

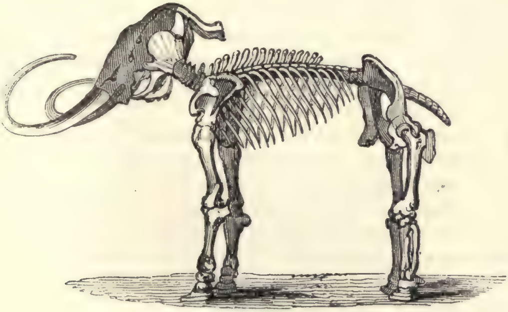


FIG. 243.—Elephas primigenius.

side of both jaws. They are composed of plates of dentine and of enamel, united by a third, or cortical substance; the lines of enamel present a different mode of arrangement in the African, Indian, and fossil species, as shown in the sub-

joined sketch. (Fig. 242.) The singular mode of growth of the molar teeth in the elephant accounts for the inequality of their number in the jaws. In mammals, in general, the teeth rise from below upwards, whilst in the elephant they grow from behind, forwards. We know from six to eight fossil species; the best known is the mammoth, *E. primigenius*, characterised by molars, with narrow plates, which resembled those of the Asiatic more than the African species. (Fig. 242.) The skull was larger, the tusks longer, and more bent. The remains of this gigantic mammal attest that it had a very wide geographical range during the period that preceded the last great catastrophe of the earth, as it is found in the drift of Europe, North America, and the north of Asia, towards the polar circle, but especially in Siberia; a mammoth was found near the borders of the glacial sea, recently detached from a block of ice, with its flesh preserved. Its skin was covered with a species of long woolly hair, evidently adapted to protect it from the rigours of a cold climate: the teeth of this species are found in the drift (fig. 239) and caverns of England. Those of Banwell, in the Mendip Hills, may be cited as localities where many fine tusks, molars, and portions of the skeleton have been discovered.* Other species have been found imbedded in the superficial deposits of France, Italy, and Belgium. A fine skull, with tusks, of a new species, was obtained by Cautley and Falconer from the sub-apennine stage at the base of the Himalaya Mountains.

4th Order.—EDENTATA.—This order forms a transition series between the mammifera with nails, and those with hoofs. Their feet are surrounded with a thick scaly integument, and the toes are often armed with arched robust claws, which embrace the phalanges: with one or two exceptions, they have no incisor teeth; hence the name of the order. Their movements are very slow: the irritability of the muscles remains for a long time after death: their brain is small, and the tegumentary membrane is covered with a scaly, horny, or bony armour. They appear to connect the classes mammalia and reptilia with each other. In our day, the Edentata are found only in the tropical regions of the

* Mr. Beard, of Banwell, has made a large and most interesting collection of fossil bones from these caverns.

old and new worlds, whilst during the tertiary epoch they extended their range into France and Germany.

We divide the order into four families :—

First Family.—The MYRMECOPHAGÆ, which have the ant-eaters for their type, have the jaws, in some edentulous. To this family belong three extinct genera. *Glossotherium*, from the Pampas of Buenos Ayres, and the caverns of Brazil; *Macrotherium*, found by Lartet in the miocene stage of Sansan; it had the phalanges and claws of the ant-eaters,

FIG. 244.—Myrmecophaga jubata.

and teeth similar to the sloths, without roots or enamel. Of the existing genus *Myrmecophaga* (fig. 244), fossil species are found in the caverns of Brazil, and of *Orycteropus*, in the sub-apennine stage of the Pampas.

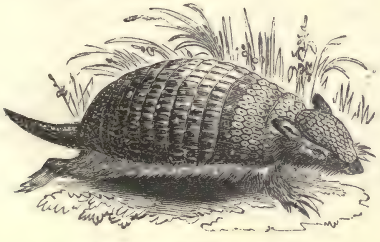


FIG. 245.—Dasypus sexcinctus.

Second Family.—The DASYPIDÆ have for their type the *Dasypus* or armadillos. (Fig. 245.) Their body is enclosed

in a hard, horny, or osseous crust, composed of innumerable pieces, inlaid like mosaic, which covers the head, body, and tail. This forms a shield which protects the front of the body, and an extensive cuirass for the shoulders, and the croup. A series of intermediate transverse moveable bands permit the animal to roll itself into a ball like a hedgehog. The tail is often encircled with rings of this substance, and there are numerous plates on the legs.

Amongst the most extraordinary of the extinct genera of this family, is the *Glyptodon*, or gigantic armadillo, which in the structure of the skull, and form of the ascending branch of the zygomatic arch, resembles the *Dasypus*, and connects that genus with the *Megatherium*. The molars $\frac{8}{8}\text{-}\frac{8}{8}$ approach those of the armadillos in structure; their external surface is grooved with two deep furrows, which divide the surface of the tooth into three lobes—hence the name. The hind feet have a remarkable form ; the metatarsal bones are large and massive; the nail phalanges are short and depressed. The *Glyptodon* was protected by a solid coat of mail, composed of innumerable plates united by serrated sutures. Internally these plates appear hexagonal, but externally they form a mosaic of rosette-like figures. Its gigantic remains were found in the sub-apennine stage of the Pampas of Buenos Ayres ; they now enrich the museum of the College of Surgeons, London. Fragments of the bony cuirass of *Glyptodon* were supposed, before the discovery of this splendid specimen, to belong to the *Megatherium*.*

Chlamydotherium, *Hoplophorus*, *Pachytherium*, *Euryodon*, *Xenurus*, are fossil genera which have been found by Lund in the ossiferous caverns of Brazil. Gigantic fossil species of the existing genus *Dasypus*, have been found in the sub-apennine stage of France, and in the caverns of North and South America. *Dasypus* and *Macrotherium* are the only edentate mammals found fossil in Europe.

Third Family.—The MEGATHERIDÆ is composed of gigantic slow-moving extinct genera, of which the *Megatherium* is typical. The skeleton (see fig. 182) was found on the banks of the Luxan, about three leagues from Buenos Ayres. Similar remains have been found at Lima, and likewise at

* Buckland's Bridgewater Treatise, p. 160.

Paraguay. Sir Woodbine Parish, in 1832, obtained from the bed of the Salado, portions of a skeleton which are now in the College of Surgeons. The height of this gigantic mammal was nearly that of an elephant, and larger than the rhinoceros. Its skull resembled that of the sloth, and is small when compared with the bulk of the body: its jaws are without incisors and canines; it had molars, to the number of $\frac{5}{4}\frac{5}{4}$, of a prismatic form, from seven to nine inches in length, and deeply and solidly imbedded in their sockets. Like the molars of the elephant, they are composed of dentine, enamel, and cement. These elements are so disposed that the wearing of each crown forms two triangles, which interlock into corresponding spaces in the opposing jaw. The mouth was an engine of enormous power, adapted for bruising roots or other vegetable substances. It had ponderous extremities, armed with claws. Its hind-legs were far more colossal than those of the elephant, and its tail so far exceeded, in the dimensions of its vertebræ, the size of that organ in other mammals, that it is supposed it was used with the hind-legs to form a tripod for supporting the animal, whilst the fore-limbs were employed for digging. It possessed clavicles, and could use the anterior extremities. It has been observed by Dr. Buckland,* that "his entire frame was an apparatus of colossal mechanism, adapted exactly to the work it had to do; strong and ponderous in proportion as this work was heavy, and calculated to be the vehicle of life and enjoyment to a gigantic race of quadrupeds, which, though they have ceased to be counted among the living inhabitants of our planet, have, in their fossil bones, left behind them imperishable monuments of the consummate skill with which they were constructed. Each limb and fragment of a limb forming co-ordinate parts of a well-adjusted and perfect whole; and through all their deviations from the form and proportion of the limbs of other quadrupeds, affording fresh proofs of the infinitely varied and inexhaustible contrivances of Creative Wisdom."

Mylodon had the ponderous body of the *Megatherium*. A fine skeleton of *M. robustus* is in the museum of the College of Surgeons.

* Bridgewater Treatise, p. 164.

Sælidotherium and *Platyonyx* are from the sub-apennine stage of the Pampas; and *Cælodon* and *Sphenodon* are found in the caverns of Brazil.

FIG. 246.—Chincella lanigera.

5th Order.—RODENTIA (or Gnawers).—Form a natural order of unguiculated animals, whose dentition consists of incisor and molar teeth. The canines are absent, and there is a considerable vacant space between the incisors and the molars. (Fig. 247.) The incisors, generally $\frac{2}{2}$, are long, arched, and deeply implanted in the jaw; the front of the tooth is thickly coated with enamel; the cutting-edge is chisel-shaped; and the tooth is constantly growing and advancing in the jaw, to supply the wear and tear occasioned by the gnawing habits of the rodents. The molars have large crowns; the dentine is variously intersected with seams of enamel. The lower jaw is articulated to the skull by a longitudinal condyle, which permits a backward and forward movement in this organ, by which they are enabled to gnaw and chisel away very hard bodies. The rodents are in general small animals, and we observe a considerable disproportion between the front and the hind extremities (fig. 246). We know many fossil genera, as the *Archæomys*, from the falunian stage of Auvergne;

FIG. 247.
Skull of a Squirrel.

Lonchophorus, from the caverns of Brazil; *Trogontherium*, *Steneofiber*, *Palæomys*, *Chalichomys*, *Chelodus*, from the falunian stage; and *Theridomys*, from the sub-apennine stage of France and Germany. Fossil species of existing genera are found in the different stages of the tertiary epoch, and in the caverns of the old and new world.

6th Order.—CHEIROPTERA (or bats).—Have the bones of the anterior extremities greatly developed, and the fingers much elongated to support a delicate membrane. By this metamorphosis the arm and hand is adapted to form a wing. The fossil species of this order belong to existing genera. They are found in the eocene and miocene stages of England and France, the miocene stage of Germany, and in the caverns of Europe and South America.

7th Order.—AMPHIBIA—which includes the seals. Have the extremities modified and arranged for swimming. To this order belongs the *Trichechus*, which frequents the seas

FIG. 248.—Felis tigris.

of the north. Fossil species of this genus are found in the middle stage of the tertiarics of France and England.

8th Order.—CARNIVORA.—Have the jaws armed with incisor, canine, and molar teeth (fig. 249): the tiger is typical

of this group. (Fig. 248.) Among the *Plantigrade* tribe which walk upon the soles of their feet, we recognise in a fossil state several extinct species of *Ursus* (bears). The remains of *U. cultridens* have been found in the falunian stage of Sansan, in Bavaria, and in the sub-apennine stage of the Val d'Arno, Montpellier, and Puy-de-Dôme. The ossiferous caverns of England, France, and Germany, contain immense numbers of *U. spelæus*, and six other distinct species.

We know likewise several extinct genera, as *Agnotherium*, from the cavern at Eppelsheim; *Amphicyon*, from the falunian stage at Sansan; *Tænotherium*, from the eocene of Montmartre; whilst in the caverns of France, England, Belgium, and Germany, is found an extinct species of badger (*Meles antediluvianus.*).

Belonging to the tribe of *Digitigrade* carnivora, or those which walk on their toes as the dog, many extinct species of existing genera are known. The most remarkable of these are the fossil hyænas, found in the bone caverns of Europe, and especially of those at Kirkdale, and of one near Banwell in Somersetshire. The latter was unquestionably a den inhabited by these carnivora. We have before us a lower-jaw, presented by Mr. Beard, which measures from the carnassier molar to the median line, five inches and three quarters; and transversely from molar to molar, four and a half inches. The teeth are blunted, and the jaw is above one-third larger than that of the largest living species. Along with the hyæna's jaws, were the bones and skull of a young rhinoceros, which bore the imprints of teeth-marks, the body having been apparently dragged into this retreat.

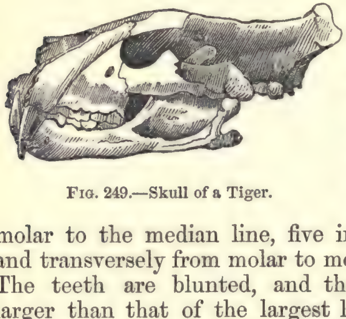


FIG. 249.—Skull of a Tiger.

About twenty species belonging to the genus *Canis* have been found in the eocene stage of France; and more than the same number of the genus *Felis* in the upper stages. Of genera which are now extinct, may be cited *Machairodus* and *Amyxodon*, from the middle tertiaries, and *Hyænodon*, from the eocene of the Isle of Wight and of Auvergne.

9th Order.—QUADRUMANA.—The existence of this order in a fossil state is a recent discovery, and it is remarkable, that about the same time the remains of monkeys were found in the tertiary strata of Europe, Asia, and America. The quadrumana are characterised by the four hands which terminate their extremities, in each of which the thumb is opposable to the fingers. They have incisor, canine, and molar teeth. In the general structure of their skeleton in the development of their brain, nervous system, and the organs of the senses, as well as in their digestive organs they approach near to man. We divide the order into two tribes :—

1st Tribe.—The monkeys of the Old World, which have twenty molars.

2nd Tribe.—The monkeys of the New World, which have twenty-four molars.

The *Monkeys of the Old World* have, like man, four vertical incisors. Two canine, and ten molars in each jaw. To this tribe belongs the jaw of the *Macacus*, obtained from the eocene sand of Kyson, in Suffolk, of which we subjoin the figures 250 and 251, and description, given by Professor Owen, in whose hands the specimen was placed for identification :—*

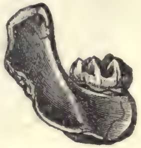


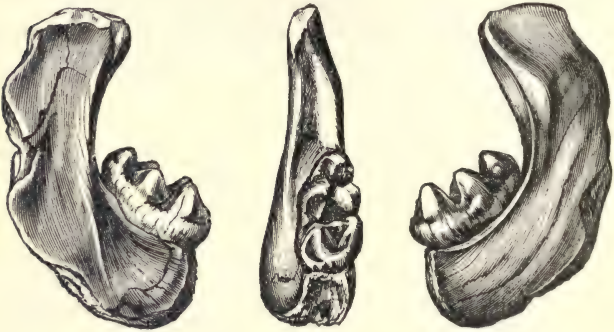
FIG. 250.—Jaw and tooth of macacus, natural size.

"The fossil exhibits the following differences from the recent *Macaci* :—The whole tooth is rather narrower in proportion to its length ; the transverse ridge at the anterior part of the tooth, crossing the base of the two anterior tubercles, is a little more prominent, and passes more obliquely from the outer to the inner side ; the second transverse ridge, uniting the first pair of tubercles, rises nearer to their summits. The portion of jaw is more compressed than the corresponding part of the jaw in the recent *Macaci* (compare fig. 251, *B.*) ; the internal wall of the socket of the tooth is flatter and much thinner ; (this character of the fossil is well shown in fig. 251, *C.*) ; the ridge on the outer side of the *alveolus*, which forms the commencement of the anterior margin of the coronoid process, begins closer to the tooth (as is shown in figs. 250 and 251, *A*).

* Mag. of Nat. History, vol. iii., New Series, page 446.

"These characters are sufficiently important and well-marked to establish the specific distinction of the macacque, to which the portion of jaw belongs, and are the more valuable as corroborating the evidence already adduced in proof that the fragment in question is a true fossil of the stratum in which it was discovered.

"Fossil remains of *Quadrumana* have been found, within a recent period, in the tertiary formations of India, of the South of France, and of the Brazils.



A B C

FIG. 251. A is the same jaw, magnified two diameters.
B is a view of the fossil looking down upon the grinding surface of the tooth, similarly magnified. It does not show distinctly the inner small cusp of the 'talon' or hinder tubercle.
C is a view of the fossil from the inner side, magnified two diameters.

"The Indian remains, discovered by Messrs. Baker and Durand, and those subsequently found by Messrs. Falconer and Cautley, have been referred to a species of *Semnopithecus* as large as the *Entellus*, and consequently exceeding considerably the present fossil in size.

"The portions of fossil quadrumanous lower jaw discovered by M. Lartet, in the South of France, indicate a species of *Hylobates*, rather smaller than the *Syndactylus*, but nearly allied to that species.

"The South American extinct quadrumanes, discovered by M. Lund, in the basin of the Rio des Velhas, it is interesting to find, are referable to a form peculiar to the New World,

and are most nearly allied to the genus *Callithrix*, but the extinct species are more than double the stature of any of those which exist at the present day.

"Not only, therefore, is the fact of the existence of quadrumanous mammals, during the tertiary period of the earth's history demonstrated; but we have evidence that four of the modifications of the quadrumanous type at present recognised, were in being at that remote epoch: that is to say, the tailless ape (*Hylobates*), the gentle vegetable-feeding semnopithecque, distinguished by its complicated stomach; the more petulant and omnivorous macacque, and the platyrrhine (*Callithrix*).

"Lastly, we have the interesting fact established, that the *Quadrumana* were formerly distributed over parts of the earth's surface, which at the present day are so far altered as regards the climate and vegetable productions, as to be unfit for their existence."

De Blainville described as *Pithecus antiquus*, a nearly perfect lower jaw, found by M. Lartet, in the fresh-water strata of the falunian stage at Sansan (Gers.) 43° North latitude.

M. Lund discovered in the caverns of Brazil, the bones of extinct species of American genera, with those of an extinct genus, *Proto-pithecus*. So that the structural characters which are found to coincide with the geographical distribution of this order were the same during the tertiary as in the modern epoch.

10th Order.—BIMANA.—The remains of fossil animals, an outline of which we have thus imperfectly sketched, are all found embedded in the different stages of the stratified rocks.

It is, however, otherwise with the bones of *Man*, which have never been discovered in any of these stages. Human bones have been found in osseous breccias now forming, in the fissures of rocks, in the deep recesses of deserted mines, and in other excavations, or incrusted with depositions from mineral springs, or embedded with the debris of shells and corals in formations now in course of deposition.

The ancient diluvial caves of both continents contain human bones, as those of Kæstriz in Saxony, Kuhloch and Zalmloch in Franconia; those of England, Gibraltar, of France and Belgium. The alluvial deposits, more or less

ancient, contain human remains; they have been found in the *Lehm*, on the borders of the Rhine, with the remains of the species of fluviatile shells now living in that river: in the alluviums of Krems in Austria, and of Canstadt (in Wurtemberg); in North America, in the caverns of Kentucky, and in South America in those of Brazil.

Human skeletons are found embedded in a modern limestone rock, containing shells and corals of the same species as those now living in the adjoining sea at Guadaloupe, in the Antilles (fig. 253); and, lastly, human bones have been found by D'Orbigny, in the central plains of South America, on the banks of the Rio-Securi, which flows into the Amazon, in a bed of fine sand mixed with clay, at a depth of eighteen feet from the surface, along with fragments of pottery and other human works.* In all these cases, however, the deposit which contains Man's remains, belongs to a more modern era than the newest sub-apennine stage of the tertiary epoch.

In casting a retrospective glance over the series of fossil animals which we have thus rapidly reviewed, it will be observed, that we have endeavoured to show that the physiological, like the physical laws, have ever been the same, and that they exhibit in clear characters, the wisdom, foreknowledge, and design of their Great Author. The study of the phenomena which palæontology thus brings before the student, must have a salutary influence on his mind, inasmuch as it proves by cumulative evidence, that law, order, and benevolence govern all things animate and inanimate on the Earth as in the Heavens.

Geology, so far from being opposed to the religion of the Bible, is the only science capable of demonstrating that a special providence alike directs the fiery vomit of the volcano and the development of the zoophyte; it teaches Man that there was a time when no living thing animated the primeval ocean; that there was a starting point—a beginning; it shows him that the regulating hand of Omnipotence has, through all the immensity of the past, adjusted and maintained the economy of our planet; that peculiar forms of animal life were created, to perform a

* D'Orbigny, Cours elémentaire de Palæontologie, p. 162.

certain part; and when that was no longer required, they were annihilated, to give place to others better adapted, by some new feature in their organisation, to the character of the changing scene they were for a brief span designed to animate. And, finally, palæontology shows, that when the appointed time arrived, Man was placed upon the earth's surface, just at that period when the external world had been prepared, by a long series of eventful changes, for his reception; with the furniture of the universe wonderfully adapted to his nature, and calculated to arouse to action his noblest faculties. It is thus the brilliant discoveries of modern geology become the handmaids of natural theology, and show, in the most striking and satisfactory manner, the unity of the stupendous design and creative intelligence of the Great First Cause; for whilst the crust of our planet was destined by its Creator to pass through a series of successive though turbulent changes, still do we find the structure and functions of the myriads of animals that have lived and died upon its surface, through all the periods of geological chronology, to present the same exquisite organisation—the same perfect adaptation to surrounding Nature, and to their varied habits and instincts, as the countless numbers of happy beings that fill with life and activity, the air, the earth, and the waters of the present day.

CHAPTER IX.

SPECIAL GEOLOGY.

Modern Geological Changes.

Before we enter on the history of the past, we shall direct the student's attention to the present; and previously to describing the vicissitudes which the earth has undergone during the remote epochs of its history, we purpose to devote a few pages to the account of those changes which have occurred in our own island within the historical period. The sketch must be brief; for to enumerate the whole of these would require a separate treatise.

Wherever we direct our observation, in the natural world, we discover that a law of mutation is impressed on all created objects, as one of the conditions of their existence. Every operation of Nature affords examples of this law. Heat and cold, moisture and drought, the warmth of summer and the frost of winter, the snow and the ice, perform their part in displacing and renewing the solid crust of the earth. The agencies by which these changes are effected, may be divided into destructive and conservative.

The phenomena of Nature had early engaged the attention of philosophic observers, and Ovid's description comprises the chief agencies in operation at this moment; such as the change of land to sea, and of sea to land; the excavation of valleys; the destruction of hills, and the transfer of their materials to the sea; the transition of dry ground to marshes, and the reverse; the occurrence of earthquakes, and the phenomena they produce; the union of islands with mainlands, the insulation of peninsulas, and those instances of change which characterise the varying condition of the crust of our globe. The laws of Nature

are as permanent as they are powerful, and the causes described by the poet are as energetic at present as they were twenty centuries ago, when they were enumerated. The sea is a powerful and ever-active agent of destruction; and the shores of our island present extensive proofs of its devastating power. We find that lofty cliffs and rocky promontories are in a state of decay, more or less rapid in proportion to the character of the materials which compose them, and the power they possess of resisting its abrading force. Commencing with the shores of Orkney and Shetland, we observe the effects of the waves on the primary formations of those distant isles; and proceeding to the mainland, we notice like traces of devastation along the eastern coast of Scotland, where tracts of land, villages, and towns, are recorded to have been swept away by the sea. On passing the English border, we find the coasts of Northumberland and Durham presenting similar marks of destruction, which are recorded in the historical descriptions of these districts. On the shores of Yorkshire, the same scene of devastation presents itself; several villages have been destroyed, of which, in some cases, a mere vestige, in others the name only remains, the amount of denudation depending largely on the nature of the cliffs, and their greater or less capability of resisting the waves. Thus at Bridlington,—the cliffs are composed of pliocene deposits resting on the chalk,—a great portion of which have been swept away. The town and port of Ravenspurn, at which Henry IV. landed on his enterprise of dethroning Richard II., now exists only in the historical records of that event. The low coast of Lincolnshire is protected by embankments, the destruction of which, by inundations, has at various periods occasioned the most disastrous results. Tracts of this fenny district, embanked and drained by the Romans, were lost after the departure of that people, by the decay of the barriers, and the inroad of the sea. The coasts of Norfolk and Suffolk, being composed of softer materials, exhibit a striking example of the destructive power of the ocean in the ruin of the cliffs; while the deposit of bars and sand-banks, composed of the detritus thereof, act as barriers, and prevent its farther encroachments. While tracts of land and villages, together with the old town of Cromer and of Dunwich, have been swept away by the ocean,

various districts have been won from the deep. History and tradition record the fact that the sea once extended to Norwich, on an arm of which, it is recorded in Saxon manuscripts to have been situated; while ancient cliffs existing far inland, prove that the sea has receded still more considerably from its ancient limits. Extensive devastation is observed along the coast of Essex, which is largely composed of strata appertaining to the London clay formation. The town of Harwich, stated to be the representative of a more ancient submerged town, called Orwell, is in inevitable danger of sharing the fate of its predecessor. The coasts which surround the estuary of the Thames present examples of the countervailing destruction and restoration of the land. While the cliffs of the Isle of Sheppey, which consist solely of London clay, are constantly wearing away, the channel which separated the Isle of Thanet from the mainland of Kent, has shoaled up and formed new land. The Goodwin sands are said to have constituted the estates of Earl Goodwin, which were submerged beneath the waves. Pursuing the inquiry along the coast of Kent, we find the work of devastation still in progress. The firmer cliffs of the chalk are undermined and destroyed as surely as the more yielding strata of the London clay. The cliffs of Dover are thus sapped, and considerable falls constantly occur. At Folkstone, the same accidents are produced in a manner analogous to that which takes place at the south side of the Isle of Wight, in strata of the same geological formation, and which have given rise to the celebrated Undercliff of that island. The chalk at Folkstone rests inclined on the gault, or blue clay. The water which passes through the porous strata so moistens the clay, as to occasion the overlying mass to slide down the inclined plane formed by the subjacent deposit, and thus to produce falls of enormous extent. The sand cliffs of Hastings have suffered considerable destruction. The chalk cliffs of Beachy Head have undergone like abrasion and disintegration. An enormous mass of rock, three hundred feet in length, and thirty in breadth, was precipitated some thirty years ago, and similar falls have since repeatedly occurred. At Brighton, part, though not the whole, of the ancient town was situated, in the reign of Elizabeth, under the cliffs, on the spot where the chain-pier now extends into the sea;

in the year 1665, twenty-two tenements had been ingulfed by the waters, but one hundred and thirteen still remained, which were destroyed by the great storm of 1705.* The waste still continues; the road called the Marine Parade has repeatedly been narrowed; a battery formerly stood at the bottom of the New Steine, the site of which is now swept away. Proceeding westward along the Sussex coast, we find various instances of land having been ingulfed; several large churches, built in the immediate vicinity of the sea are extremely disproportioned, in size and endowment, to the scanty population by which they are surrounded. We have already alluded to the mode by which the cliffs of the Isle of Wight are sapped, and landslips produced. The promontories and headlands on the south side of the island are composed of strata appertaining to the cretaceous period. Alum Bay and Whitecliff Bay are hollowed out of the tertiary strata (fig. 252), and the bays of Sandown and Compton of the equally yielding beds of clay and sand belonging to the wealden, and neocomian rocks.

In investigating the southern coast, we find the same conditions prevailing; the bays are scooped out of softer deposits, while the harder rocks, which have withstood the action of the waves, constitute the promontories and headlands. The latter are in a continual course of abrasion, their destruction being more rapid where the substratum consists of clay. Such is the case in the Isle of Wight, and the peninsulas of Portland and Purbeck. The great landslip of December 24th, 1839, which occurred on the coast between Lyme and Axminster, was produced under similar circumstances, the upper beds consisting of strata belonging to the chalk and greensand formations; the lower being composed of clay appertaining to the lias. The springs traversing the greensand had previously loosened the upper beds, and, by moistening the clay, produced frequent falls, forming a kind of undercliff. On this occasion, the season had been unusually wet, and the upper strata having become saturated with moisture, the clays had been rendered slippery, and the entire mass was set in motion, the whole of the beds above the lias, comprising masses of chalk, chert, and greensand,

* Dr. Mantell's Geology of Sussex.

were precipitated over the subjacent beds of lias. The neighbouring coast of Devon presents evidence of like action; but, owing to the firmer nature of the rocks of that district, consisting largely of sandstones and limestones, appertaining to the Devonian and carboniferous groups, the action of the waves is less evident, and appears to have been less rapid; while on the adjacent shore of Cornwall, the still harder and more crystalline character of the plutonic rocks, the granites, syenites, greenstones, and the like, evince feebler marks of the agency of the sea, and no perceptible change, of any importance, is recorded as having taken place in the configuration of the coast during the records of man. The general principles, which are remarked in other localities are observable here; the softer rocks being gradually hollowed out into creeks and bays, while the harder strata are left to protrude as headlands; the results being proportionate to the various causes arising from the unequal resistance of the rocks, the power of currents, tides, waves, and breakers, and the original form of the coast line. Proceeding round the Land's End, the same description applies to the northern shores of Devon, Somerset, and the adjacent district of Wales. On the Cheshire coast, the cliffs, composed of the softer clays and marls of the new red sandstone have yielded immensely to the advance of the ocean, and though in the estuary of the Severn, land both in Somersetshire and Gloucestershire, has, to a considerable extent, been formed, yet the loss on this part of the coast far exceeds the gain.

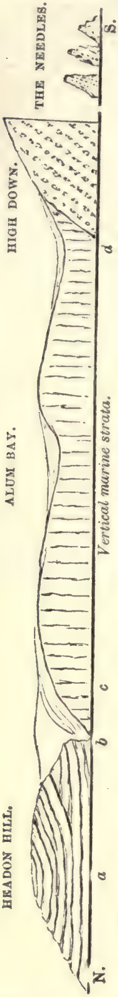


FIG. 252.—Diagram of the Eocene Strata at Alum Bay and Headon Hill Isle of Wight

It has been already observed, that the action of the sea is materially assisted by the percolation of rain, and the operation of frosts. Where the cliffs, instead of being of a homogeneous nature to their base, are composed, in their lower portions, of an impermeable substance, such as clay, the upper portions are increased in weight by the infiltration of water, while the lower are moistened and rendered slippery, so that the upper masses glide down and occasion a fall. Frosts prove a like important agent of destruction, fracturing various portions of the mass, by the expansion of the contained water in the act of freezing, which portions are subsequently detached by their own gravity. The cliff thus attacked, becomes readily disintegrated: and, from a due consideration of these causes, we cease to wonder at the extensive ruin observable in all the less resisting strata, from the coasts of Yorkshire to those of Sussex, and thence, to a greater or less extent, to the shores of Cheshire and the coasts of Scotland.

To enumerate all the instances of the destructive effects of aqueous agency, observable over the earth, would far exceed our limits; it may be sufficient to state, that the same principles universally prevail: the harder rocks stand out as headlands, after the softer deposits have been worn into bays, the action of the sea being modified by local causes, as the form of the land, the course of tides, waves, breakers, and currents.

Fluviatile Action.—Rivers are alike destructive of the banks through which they flow; especially in the case of floods, torrents, and inundations occasioned by rain and the melting of snow; the ravages they effect can hardly be credited by those who have not directed their attention to this class of agents. These phenomena are more strikingly developed on the continents of Asia, Africa, and America, the rivers of which constitute the drainage of great tracts of land. We must refer the student to the works on this branch of our subject, in which fluviatile action is discussed in the most ample and satisfactory manner.

Atmospheric Agency.—The agency of the atmosphere is both chemical and mechanical. The absorption of oxygen and carbonic acid from the air, causes rocks of all classes to disintegrate. The mechanical agency consists, in the first

place, in the abrading force of running water, by which the solid materials of the earth are continually worn off and transferred to the beds of adjacent seas; and, secondly, in the fissuring and cleaving of rocks, by the expansive power of frost.

As the agencies above mentioned are chiefly referable to destructive causes, and are attributed to the action of water, those of a renovative nature are assigned to elevating forces, and are principally due to the agency of fire. By these antagonistic powers, the solid crust of the earth is changed and renewed. The agency of heat is manifested, either by the rapid effects of the volcano, or the slower process of gradual upheaval; the former being exemplified by the raising of Monte Nuovo in a night, the latter by the uplifting of Sweden and part of Scandinavia by gradual continental elevation.

The conservative principle is also exemplified in the tendency of the materials derived from the destruction of pre-existing rocks, to become consolidated into new strata, by means of cement, either of a siliceous, calcareous, or ferruginous nature. The production of silex, which is far more abundant in the older formations than in those of recent date, constitutes a problem which the present state of our knowledge does not enable us to solve. The siliceous deposits of the springs of Carlsbad, and, in particular, the Geysers of Iceland, are due to the action of thermal agents produced by the internal heat of the earth, which, it is supposed, was more active during the earlier periods of its history than at present. The nature of calcareous cement is more easily explained. Most fresh water holds a certain quantity of carbonic acid gas and carbonate of lime in solution. A change of temperature liberates the gas, and the lime is, in consequence, precipitated. Streams thus impregnated flowing over loose materials, as sand, pebbles, &c., have the effect of cementing them into rock, and producing limestone, calcareous sandstone, or conglomerate; while waters holding iron in solution, cement similar substances into conglomerations of a ferruginous nature.

Rivers exemplify the conservative principle, in the formation of deltas at their junction with the sea, by which the materials they have abraded and swept away are thrown

down as new deposits. The most striking instances are furnished by the Delta of the Nile, and the large rivers of the American continent.

In addition to these mechanical agencies, we have already alluded to the fact, that vital action is employed in the construction of new formations. The coral polype is ceaselessly at work, rearing, first, its reefs, then its islands above the surface of the deep, and, finally, by the union of these, producing continents, which at a future period will rival those already in existence.

The limestone of Guadaloupe, celebrated for the human skeletons embedded in it, is a recent deposit, formed by the following process:—The coral reefs which surround the island are abraded by the incessant action of the waves. The detritus thus produced, is drifted to the shore in the state of coralline sand or mud, where, by the action of the atmosphere, or streams holding carbonate of lime in solution, the mass becomes indurated, and forms a compact limestone. It is evident that the rock was in a plastic state when these skeletons were placed in it, and it is also ascertained that the bones are not fossilised, but retain their animal matter and phosphate of lime. There is not sufficient evidence as to the mode in which they have been embedded, whether they are the relics of a battle, or were deposited as a mode of sepulture. General Erneuf, mentions a massacre of the Galibi tribe by the Caribs to have taken place, 130 years since, on this spot: but Dr. Moultrie, who possesses the skull belonging to the specimen in the British Museum, declares it to be that of a Peruvian, or a race possessing a similar form of skull. A skeleton, now in the Museum of Natural History at Paris, was discovered in a sitting position, which is known to be the usual interment posture adopted by the aborigines of these regions. The accompanying figure (253) represents the skeleton from Guadaloupe in the British Museum.

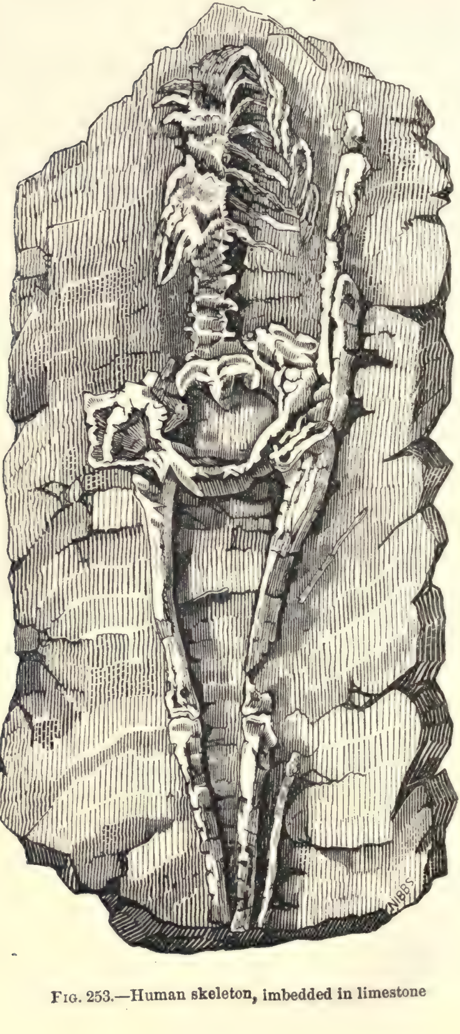


Fig. 253.—Human skeleton, imbedded in limestone

CHAPTER XI.

TERTIARY PERIOD.

Tertiary System, Supracretaceous Group of English; Terrains de Sediment Superieurs of French; Tertiärgebilde of German Authors.

Authors:—Lyell, Charlesworth, Webster, Prestwich, Scrope, Horner, Cuvier, Brongniart, Constant Prevost, Wright, &c., &c.

Collections:—Geological Society, those of the Marchioness of Hastings, Mr. Bowerbank, Mr. Saull, Mr. F. Edwards, and Mr. S. V. Wood, Private Cabinets in Suffolk, Norfolk, Isle of Wight, London.

Having described the studies which are essential to the geologist, and suggested the best mode of pursuing them; we shall now sketch a compendious account of the various geological periods, and the stages into which they are divided. The student will find his inquiries assisted, by impressing on his memory, at an early period of his studies, some striking facts, characteristic of each period and stage, by which they may be recognised. Thus, the varied deposits, fluviatile, lacustrine, marine, and volcanic, which constitute the tertiary system, may be distinguished by the following general features:—

1. They are deposited in depressions, usually of the chalk, and occasionally of the older rocks.

2. They evince proofs of important changes in the relative level of land and sea.

3. They afford evidence that, during this epoch, part of Europe was the site of great lakes, which, at the present day, have their analogues in the American continent.

4. They show that volcanic agency was then developed on a vast and magnificent scale.

5. They testify the gradual refrigeration which took place during this epoch, and the approximation consequent on change of climate, to the forms of vegetable and animal life prevailing at the present day.

6. Finally, owing to their position at the surface, and having undergone less pressure than the rocks beneath, they constitute a vast depository of fossil shells, which are preserved in such number and perfection, as to form a scale by which the relative ages of these formations may be determined.

M. Deshayes, whose work on the fossil shells of the Paris beds will long remain a monument of his profound knowledge of conchology, divided the European tertiary strata into three groups, founded upon the proportion of existing species which they contain. The following table exhibits the groups, the per-centage of the recent species, and the localities where they are developed :—

Stages.	Localities.
Upper Group, 49 per cent.	Sicily; the sub-apennine beds; Perpignan, Morea, and the Norfolk crag.
Middle Group, 18 per cent.	Faluns of Touraine; Dax; Bordeaux; Suffolk Crag; Turin; Baden; Vienna; Angers; Rouca. The Viennese and Baden fossils are typical of those of Moravia, Hungary, Cracovia, Volhynia, Podolia, and Transylvania.
Lower Group, 3½ per cent.	Paris; London; Hants; Isle of Wight, Valognes; Belgium. The fossils of Castel Gomberto and Pauliac are nearly the same as the Parisian series.

By independent investigations on the tertiary strata of Europe, Sir C. Lyell* grouped the beds into four divisions, founded on the proportion of existing species they severally contained. The result of our distinguished countryman's labours confirmed those of M. Deshayes.

In certain deposits he found that out of a hundred shells there were no more than three which were identical with living forms; in other beds the proportion increased to seventeen; while, in others, the numbers varied from about thirty-five to upwards of ninety per cent. Inferring, therefore, that the relative age of these deposits might be determined by the number of existing shells they respectively contained, he assigned the three per cent. beds to the oldest term, calling them *eocene*, from ἠως, aurora, and καινος, recens, indicating the dawn of the new or recent period; the seventeen per cent. to the *miocene*, or middle, from μειων, minor, and καινος, recens, signifying that these beds contained a

* Principles of Geology, 2nd Edition.

minority of recent shells; and the remaining deposits to the *pliocene*, or modern, from *πλειων*, major, and *καινος*, recens, showing that these deposits contain a majority of recent shells. He subdivided this latter class again as follows:—the beds which contained fifty per cent. of existing shells were termed older pliocene, while those which presented ninety in a hundred of living forms were named newer pliocene. The student will best understand the whole as signifying ancient tertiary, middle tertiary, and modern tertiary; subdividing the latter into early modern tertiary, and later modern tertiary.

Alcide D'Orbigny divides the tertiary period into four stages, each characterised by a special fauna; which he has named Sub-apennine, Falunian, Parisian, and Suessonian; these four stages contain 6,040 species of mollusca and radiata, the distribution of which is shown in this table:—

STAGES.	Number of species of Mollusca.	Number of species of Radiata.	Total Number of species.	
Sub-apennine . . .	444	162	606	6,040
Falunian	2,903	160	3,063	
Parisian . . .	1,478	199	1,677	
Suessonian . . .	562	132	694	

GEOGRAPHICAL DISTRIBUTION OF THE TERTIARY STRATA.—They prevail extensively in this country, but are more largely developed on the continent of Europe, occurring in France, Italy, Sicily, Germany, and in Asia, Africa, America, and Australia.

FIG. 252.—Volùta Lambérti, Red crag.

FIG. 253.—Fusus contrarius, Red crag.

The marine deposits of the valley of the Clyde, near Glasgow, which contain from 85-90 per cent. of existing species, represent the newer pliocene; whilst the crag of Norfolk is regarded as older pliocene, the red and coralline crag of Suffolk is referred to the miocene group.

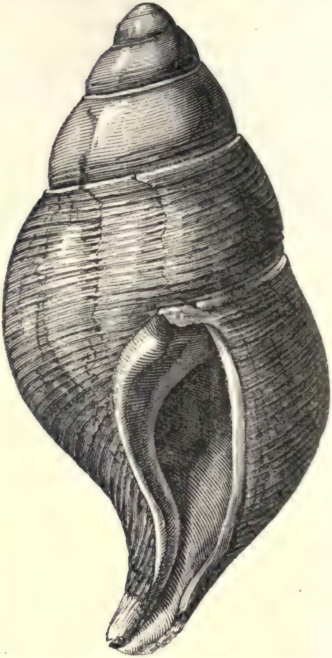


FIG. 254.—Trophon elegans, ventral side, from the red crag.

The stratigraphical order of the crag was determined by Mr. Charlesworth,* to be:—

1. The mammaliferous or Norwich crag.
2. The red crag.
3. The coralline crag.

The *mammaliferous crag* consists of shelly beds of sand,

* In a paper read to the British Association, in 1836.

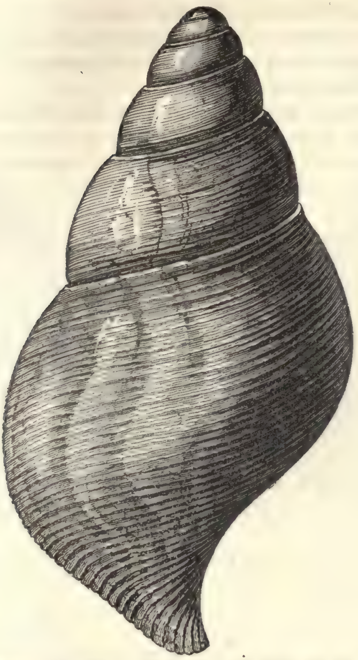


FIG. 255.—Trophon elegans, dorsal side, from the red crag.

laminated clay and loam, with layers of flinty shingle reposing on chalk, and generally covered with a thick bed of gravel: this stratum contains about a hundred species of

FIG 256.—Natica glaucinoides, Cor. crag.

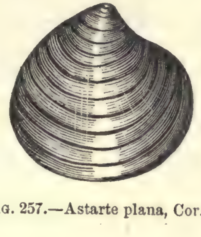


FIG. 257.—Astarte plana, Cor. crag.

mollusca, about twenty of which are land and fresh-water shells. With these are found remains of fishes, *Platax*, *Myliobates*, and mammalian remains of mastodon, elephant, horse, pig, &c., and also bones of birds.

The *red crag* is a shelly sand of a deep ferruginous colour containing an abundance of marine shells, many of which are much rolled or water-worn, the layers of which are obliquely disposed from some irregular movement during their deposition. Between two and three hundred species of mollusca are found in this bed, of which figs. 252, 253, 254, 255, are very characteristic.

The *coralline crag* consists of a loose mass of shells and corals, imbedded in calcareous sand; or it is compact, and forms flaggy beds of limestone, with bands of greenish marl. Some of the harder parts are employed as a building material; its fossil remains consist of spongidæ, corals, and echinoderms, with about four hundred species of mollusca, of which figs. 256 and 257 are characteristic. It has been ascertained that the coralline crag was partially consolidated before the deposition of the red crag, as its surface has been denuded, and perforated with *Pholades*, which lived in the sea that deposited the latter.*

A tooth of a gigantic *Carcharias* (fig. 258), found in the red crag of Suffolk, and described by Mr. Charlesworth,† proves that enormous sharks inhabited the shores of our island during the miocene stage.

Sir Charles Lyell gives the following table, illustrative of the numerical proportion of recent and fossil species of mollusca, from the stages of the English tertiary period.

Periods.	Localities.	Per centage.	Number of Sp. compared.
Post. Pliocene	Fresh water of the valley of the Thames	99 to 100	40
Newer Pliocene	Marine, near Glasgow	85 to 90	160
Older Pliocene	Mammaliferous, or Norwich crag	60 to 70	111
Miocene	Red and Coralline, or Suffolk crag	20 to 30	450
Eocene	London, Hampshire basins	1 or 2	400

* Tennant's British Fossils.

† Magazine of Natural History, new series, vol. i. p. 226.

Judging from the character of the crag fauna, it has been conjectured that these deposits were formed in a sea of moderate depth, from fifteen to twenty-five fathoms. Many of the species formerly known only as fossils of the crag, and supposed to have died out, have been dredged up in a living

Fig. 258.—Carcharias megalodon, Red crag.

state from depths not previously explored. The crag fauna has therefore been found to approach much nearer to the recent fauna of the Northern British and Mediterranean seas than had been imagined. The analogy of the whole group of testacea to the European type is very marked, whether we refer to the large development of certain genera in number of species, or to their size, or to the suppression or feeble representation of others. The indication also afforded by the entire fauna of a climate not much warmer than that now prevailing in corresponding latitudes, prepares us to believe that they are not of higher antiquity than the older Pliocene era.*

The deposits which occupy the basin of London, and the valley of the Thames, fill up a depression of the chalk, which, commencing from the North Downs on the south, terminate on the east with the Isle of Sheppey, on the west with the sea, and are bounded on the north-west by the re-appearance of the chalk in the hills of Berkshire, Wiltshire, Oxfordshire, Buckinghamshire, and Hertfordshire. These accumulations were once divided into three distinct groups, the Bagshot sand, London clay, and Plastic clay, but, by later observers, they have been reduced to two; the first consisting of those superficial beds which compose the sands of Highgate, Hampstead, Finchley, Bagshot Heaths, and other arenaceous deposits in the vicinity of the metropolis; the second comprises those underlying deposits of shingle, clay, loam, and sand, which constitute the London clay formation.

Fig. 259.—Septarium.

The upper division of the latter is composed of indurated clays, of various tints, chiefly bluish or brown, and frequently containing ovate nodules of argillaceous limestone, divided by fissures, filled with veins of crystallised carbonate of lime or sulphate of barytes, radiating from the centre to the circumference, produced by the cracking of the clay when drying, and by the subsequent infiltration of the mineral substance into the cavities thus occasioned (fig. 259).

* Sir C. Lyell, Manual of Elementary Geology, 1851.

They are named *septaria*, and are extensively used for cement; on breaking them for this purpose, some organic substance, as a shell, plant, or fruit, is usually found constituting the nucleus of the mass. The lower division is composed of alternating beds of sand, shingle, clay, and loam, which, from some of the clays being used for pottery, occasioned the name of the Plastic clay formation to be bestowed on the entire series. The character of their embedded fossils proves the marine origin of these deposits; consisting of the teeth and vertebræ of sharks, the remains of crustacea, with those of marine mollusca and corals. The vegetable reliquiæ, consisting of the leaves, fruits, and stems of plants, with masses of wood perforated by *teredines*, evince the proximity of land, and show that these objects had been transported by rivers and tributary streams to the then existing ocean.

THE ISLE OF SHEPPEY is an outlier of the London clay. The beds are so strongly impregnated with iron pyrites as to render their contained fossils extremely liable to decomposition, and compels the collector to have recourse to particular methods, as boiling them in linseed oil, or keeping them in water, in order to preserve them. The fruits of this locality are so abundant, that Mr. Bowerbank has commenced a work devoted exclusively to their illustration. They are all of a tropical nature, and constitute an important feature of the eocene flora. By some this district was supposed to have been the site of numerous spice-islands; by others it has been regarded as an estuary deposit, and the fruits are conjectured to have been drifted by a river from the land.

Some of the characteristic shells of the London clay are represented in fig. 260.

Fig. 261 represents a piece of fossil wood, pierced by *Teredinæ*, a boring mollusk allied to the *Teredo*, which proves so destructive to the timber of vessels. The wood is now converted into a stony mass. "It must have once been buoyant and floating in the sea, when the *teredinæ* lived upon it, perforating it in all directions. But before they settled on the wood, the branch of a tree must have been floated down to the sea by a river, uprooted, perhaps, by a flood, or torn off and cast into the waves by the winds; and thus our

thoughts are carried back to a period when the tree grew for years on dry land, enjoying a fit soil and climate."

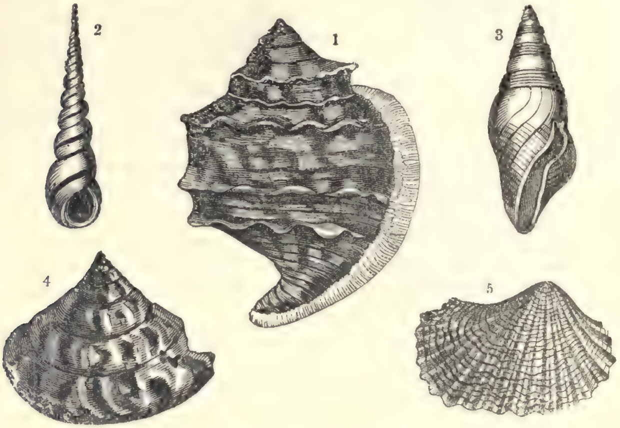


FIG. 260.—1. Cassidaria carinata. 2. Turritella edita. 3. Pleurotoma prisca. 4. Trochus agglutinans. 5. Arca interrupta.

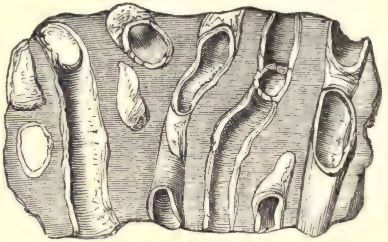


FIG. 261.—Wood perforated by Teredina personata, London clay.

BASIN OF HAMPSHIRE AND THE ISLE OF WIGHT.—We described the strata of the London Basin as being wholly marine; but in the adjacent districts of Hampshire and the Isle of Wight, we find alternations of fresh water and marine beds, indicating those important changes in the level of the land and sea to which we have already alluded. This

phenomenon is one of universal extent and influence, affecting, in fact, every portion of the surface of the globe; and as its operation has but recently been understood, it may be expedient to devote a brief space to its explanation. From the earliest observation, it was evident that existing continents had once been the bed of the sea. To explain the phenomenon, it was assumed that the sea had retired, whilst the land had retained its position. Yet since the same spot had, in many cases, been the site of sea and land, under the varied conditions of sea, estuary, island, river, and lake, it became necessary to suppose several successive retirements and returns of the water. But while such a supposition was insufficient to explain the problem, as regarded the sea, it proved inapplicable to the land; far from affording evidence of having always remained in a tranquil position, the land offered, in its dislocations and disturbances, its fractures and fissures, its elevations and subsidences, incontestable proofs that it had been the scene of the changes in question, and that their occurrence was to be explained by alterations in the level of the land, and not of the sea.

Temple of Jupiter Serapis.—The fact that the land has been raised, and not the sea lowered, has received abundant confirmation. In the bay of Baiæ, near Naples, some pillars and other fragments of a Roman building were long known to exist. They were supposed to be the remains of a Temple of Jupiter Serapis, though modern antiquaries have shown, that the worship of the Egyptian deity was proscribed to the Roman people, at the period presumed to be that of their erection, and that these relics are, probably, the ruins of an extensive suite of *thermæ*, or baths. After having excited the interest of the antiquary, the attention of the naturalist was drawn to the phenomenon of certain perforations exhibited in the three remaining pillars, at about twenty feet from the ground. It is well known that *Lithodomi* live only in the sea, bore into calcareous rocks, and exist in the apertures thus made. The perforations in these columns were effected by mollusks of this family. From this, and other facts, it has been demonstrated that the columns have suffered, since their erection, a submersion beneath the sea, a long sojourn there, and a subsequent

elevation of, at least, twenty-three feet, such being the height of the upper band of perforations. The movement is ascribed

Fig. 262.—Temple of Serapis.

to volcanic agency, the whole district around being volcanic, and the rise and the submergence of the temple is attributed to the elevation and depression of the strata on which the structure was erected.

The movement appears to have been extremely gradual, for it has been ascertained by Italian geologists, that the pillars are actually sinking again, owing to the submergence of the soil; yet so gentle and imperceptible are these motions, that the shattered columns of a ruined temple have not been overturned by their operation.

Rise of Sweden.—The phenomena observed in this instance have been verified by observations in various districts, and spreading over extensive areas. Sir C. Lyell having first expressed his doubts of the alleged fact of a rise

of land in Sweden, satisfied himself by a visit to that country; that it had, for ages, been in course of elevation in some places, and of depression in others, rising in the northern, and sinking in the southern parts. He arrived at this conclusion, not only from having ascertained that the land stood higher above the sea, at the period of his visit, than had been the case twenty or thirty years before; but by discovering beds of oyster shells of existing species, in inland cliffs at some distance from the sea, he farther inferred that the rise of land had been in operation for centuries.

While this phenomenon has been noticed in a general way in Sweden, it has been observed with still greater accuracy in Italy; Signor Nicolini, a geologist of Naples, having ascertained that between 1823 and 1838 the west coast of Italy has risen 112 millimetres, or about four inches English, above the level of the sea.

The effect of earthquakes is frequently to occasion oscillations and changes of level; thus, in the visitations of 1822 and 1835, the whole coast of Chili, from the Andes far out to sea, comprising an area of 100,000 square miles, equal in extent to one half the kingdom of France, was raised to a considerable extent; and in the late fearful earthquakes which desolated the West India Islands, that of Martinique has changed its level, and undergone an oscillatory movement, being on the northern side, two feet higher above high water mark, and on the southern, two feet lower, than was the case prior to the occurrence.

Hampshire and the Isle of Wight.—Mr. Webster classified the tertiary beds of Hampshire and the Isle of Wight, into the following subdivisions, commencing with the lowest:—1st. Plastic sands and clays. 2nd. The London clay. 3d. Freshwater deposits, consisting of sandy, calcareous marls, with large quantities of freshwater shells. 4th. Clay and marl abounding in marine shells, generally of different species from those in the London clay. 5th. Upper freshwater deposits; yellowish white, or green marl, and calcareous limestone, employed for building, and forming almost one entire mass of freshwater shells, some of the chief forms of which are depicted in figure 263.

This series of tertiary beds is of considerable extent. Small portions occur near Newhaven, and Seaford, in

Sussex: while, to the westward of Brighton, the London clay rises to the surface beyond Worthing, and forms the

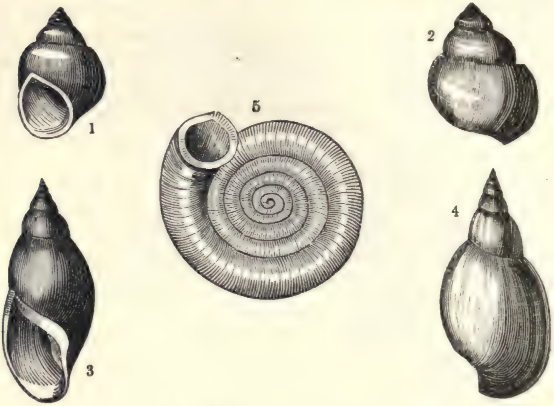


FIG. 263.—Nos. 1 and 2, Paludina concinna. 3 and 4, Lymnæa pyramidalis. 5, Planorbis euomphalus.

tract between the chalk-hills and the sea. The inland boundary stretches by Chichester, Emsworth, and Southampton to Dorchester; and the eocene beds extend over the New Forest, as far as Poole, being surrounded by a girdle of chalk. The northern half of the Isle of Wight is composed of tertiary strata; the island being, in fact, a disrupted mass of the formations of the adjacent south-east coast of England. By this disruption, the strata have undergone the most singular disturbance, the chalk has been lifted upright, and the tertiary beds with it. These results are well displayed at Alum and Whitecliff Bays, which present the phenomena of sands and clays of the most varied tints, green, yellow, red, crimson, ferruginous, white, black, and brown, all lifted to a perpendicular position, and having suffered no change, except that of having been raised, with the chalk, from a horizontal to a vertical plane. The beautiful and instructive sections of Whitecliff and Alum Bays, which should be worked by all students of tertiary geology, form the subject of an admir-

able memoir by Mr. Prestwich.* As the editor has examined and measured these beds with great care, it affords him pleasure to confirm that gentleman's accurate observations. In Dr. Mantell's beautiful work,† which should form the handbook of the student, an accurate analysis is given of all that relates to the geology of the Isle of Wight, and the annexed diagram (Fig. 264) taken from it, will render our outline of Whitecliff Bay more intelligible. This section may be regarded as typical of the British eocene, marine, estuary, and lacustrine formations. The strata measure nearly two thousand feet in thickness, and are divisible into,—1. Marine series; 2. Estuary series; 3. Freshwater series.

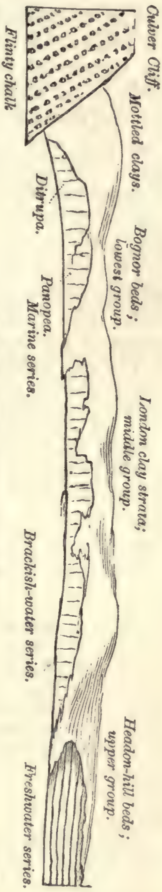


Fig. 264.—Whitecliff Bay, Isle of Wight.

The beds incline at various angles from 2° to 90°. Between the chalk of Culver Cliff and the clay is a thin seam of sand and chalk flints. This is overlaid by one hundred and forty feet of clays, beautifully mottled with red, green, brown, and puce colours, which are seen to much perfection at low-water mark. No fossils have been found therein. The next, or lowest fossiliferous group, is the representative of the *Bognor beds;* taken collectively they measure about three hundred and forty feet in thickness, and abound with the same species of shells that characterise the rocks of Bognor, as *Ditrupa*, *Venericardia*, *Pectunculus*, &c. The middle group, which succeeds, commences with a remarkable iron sandstone, which

* Geological Journal, August, 1846.
† Geological Excursions round the Isle of Wight, 1847.

defines its limits. This series measures about eight hundred and forty feet in thickness, and constitutes what was long known as the London clay. It is divisible into sixteen beds, and is composed of the *Bracklesham series*, so called from the identity of the lithological characters of the sands and the species of shells contained therein, with the sands and shells found at Bracklesham Bay; and the *Barton series* from the clays and fossils of the beds resembling those found at Barton. The next bed forms a massive cliff of fine light yellow sand, striped with ochre and ashy bands: it is the representative of the Headon Hill sands, and is two hundred feet in thickness: it contains a seam of small black flint pebbles, but no organic remains.

The upper group consists of the lower freshwater and estuary series, and measures about three hundred and fifty feet. The fossils indicate the lacustrine and estuary condition of the water in which they were deposited.

The upper Marine series is an interesting group composed of clays and marls containing an immense quantity of marine shells, as *Cytherea, Ostrea, Mactra, Psammobia, Natica, Fusus, Ancillaria, Cancellaria,* and *Balanus.*

The upper Fresh-water series, which has been much denuded, attains a thickness of 90 feet. The beds are made up of the casts of *Paludina, Melania, Melanopsis,* and other lacustrine species.

The total thickness of the entire series is about 1975 feet.

	Feet.
Of this the Mottled clays form	140
The Bognor series	340
The London clay	840
Headon-hill sands	200
Lower Freshwater and estuary	350
Upper Marine series	15
Upper Freshwater series	90
	1975 feet.

The section of Alum Bay (Fig. 250) is remarkable for the 750 feet of variously coloured sands succeeding the Bognor beds, and which represent the London clay series. It is impossible to describe the marvellous shading of these sandy strata, as they are blended together and striped like the pen-

cilling on the petals of a tulip. The coloured sands are destitute of animal remains; but seams of lignite and a few vegetable impressions are found therein. A remarkable bed of white pipe-clay is intercalated with the sands, containing beautiful impressions of the leaves of many dicotyledonous trees.

The *Barton series* contains shells identical in species with those found so abundantly in the celebrated Barton Cliff, on the opposite shore of the Solent.

The upper and lower Freshwater beds are admirably exhibited at Colwell Bay and Headon Hill, and the upper Marine stage which is intercalated between the upper and lower Freshwater beds, can be traced from the point where it rises on the shore at Colwell Bay, and ascends in its relative position in the cliff.* The beds at Alum Bay are 1664 feet thick, being about 311 less than those at White-cliff.

The Isle of Wight forms a highly interesting epitome of the whole of the formations existing in the south-east of England, comprising the marine tertiary deposit of the London basin, with freshwater strata not occurring in that locality, together with the various stages of the chalk, green sand, gault, lower green sand, and neocomian, and the lime-stones and sandstones of the wealden.

THE PARIS BASIN.—Having thus briefly described the chief British localities in which the tertiary strata are developed; the basin of the Clyde; the crag of Norfolk and Suffolk; and the basins of London and Hants; we shall now cross the Channel to inspect the more ample development of these formations on the wider area of the continent of Europe. It is a singular fact, that the capitals of England, France, and Austria, are built on the tertiary strata. The Paris basin extends over a large area, occupying a length, from north-east to south-west, of about 180 miles, and a breadth, from east to west, of about 90 miles. This space may be described as a depression in the chalk, which has been filled up by alternating groups of marine and fresh-water strata. The entire series admits of the following classification:—

* Dr. Wright on the Geology of the Isle of Wight.—Annals of Nat. History, vol. vii, page 87.

1. Upper Eocene	a. Upper freshwater limestone marls, and siliceous millstone. b. Upper marine sands, or Fontainbleau sandstone, and sand.
2. Middle Eocene	a. Lower freshwater limestone and marl, or gypseous series. b. Sandstone and sands, with marine shells (*Sables moyens*). c. *Calcaire grossier*, limestone, with marine shells. d. *Calcaire siliceux*, hard freshwater formation, contemporary with c.
3. Lower Eocene	a. Lower sands, with marine shelly beds (*lits coquilliers*). b. Lower sands, with lignite and plastic clay (*argiles plastique*).

It is assumed that an ancient gulf or depression of the chalk was filled by a sea of later date, which, extending on the north to the main ocean, was bounded on the south by a tract of land, the rivers of which brought down and deposited in its waters the spoils of the country over which they flowed, the remains of animals and plants, and the shells of the river and the land, while mineral waters were occasionally mingled with those of the sea. Changes took place in the relative level of land and water, producing fresh accumulations on the older deposits, and, after extensive vicissitudes of this nature requiring a long period of time for their development, the country rose to its present elevation.

Organic Remains.—The gypsum quarries of Montmartre had long been known to afford fossil remains. Collections of these objects had been formed, and Guettard had figured and described many of the bones and teeth. But it was reserved for the illustrious Cuvier to complete the investigations thus commenced, and to effect discoveries which have given a new impetus to scientific research. By following the principles which he had previously applied with success to the investigation of fossil elephants, he undertook the task of restoring these osseous fragments to their true place in the zoological series. His intimate knowledge of the laws of structure enabled him to refer each bone, or portion of a bone, to its approximate position in the osteology of the animal, till their novel forms, as it were, lived

and moved and had their being before him. "The essential character of a tooth, and its relation to the skull, being determined, immediately all the other elements of the fabric fell into their places, and the vertebræ, ribs, bones of the legs, thighs, and feet, seemed to arrange themselves even without my bidding, and precisely in the manner which I had predicted."*

The reptiles and the fishes approach the forms now living; the mollusca and radiata are very numerous, amounting to 1677 species, of which 1478 belong to the Mollusca, and 199 to the Radiata. They form a well-defined fauna of extinct species, a few only of which can be identified with living forms. We have already enumerated the principal families to which they belong, in our chapter on Palæontology.

Tertiary Strata of Aix.—Other groups of tertiary strata occur in various parts of France. At Aix, in Provence, are beds of marls, and freshwater limestones, which have been so gradually deposited, that even the minute and fragile forms of insect life are preserved therein. In other parts of France and Switzerland, particularly at Œningen, the thinly laminated lacustrine marls have retained, in like perfection, objects of delicate and fragile structure, as insects, and birds, the leaves and stems of plants, together with crustacea, fishes, tortoises, salamanders, and the perfect skeleton of a fox.

Strata and Organic Remains of Monte Bolca.—This celebrated mountain, situated near Verona, about fifty miles from the lagunes of Venice, has long been classic ground to the geologist, from the variety and profusion of the fossil fishes entombed in its deposits. The strata are chiefly argillaceous and calcareous, with intercalations of a cream-coloured fissile limestone, which easily separates into laminæ, of moderate thickness, containing several hundred species of fishes in the most beautiful state of preservation; the bones, scales, fins, and other delicate parts of their structure, being admirably conserved. From the volcanic character of the district, and the hill itself being capped with basalt,† it is

* Cuvier. Ossemens Fossiles.

† Parkinson. Organic Remains, vol. iii, p. 247.

presumed that the limestone in which they are embedded was injected into the ocean, in a fluid state, and that the fishes were thus suddenly destroyed.

DORMANT VOLCANOES OF CENTRAL FRANCE.—We now arrive at the description of one of the most striking features of the history of this period, the dormant volcanoes of the continent of Europe. Mr. Poulett Scrope, to whom we are indebted for an admirable account* of this interesting region, and to whose excellent work we refer for more ample particulars, remarks on the singularity of the fact, that the volcanic phenomena of central France, its plains of lava, and hills of scoriæ and ashes, which so obviously bespeak their volcanic origin, should have remained so long unnoticed and unknown; and that, up to the last half century, no one should have thought of referring these phenomena to the only agency in nature capable of producing them. This apparent blindness, he adds, is, however, very natural, and is by no means without example. The inhabitants of Herculaneum and Pompeii built their houses with the lava of Vesuvius, ploughed up its scoriæ and ashes, and gathered their chestnuts from its crater, without dreaming of their neighbourhood to a volcano which was to give the first notice of its existence by burying them under the products of its eruptions. The Catanians regarded as fables all relations of the former activity of Mount Etna, until, in 1669, half their town was overwhelmed by one of its lava currents.

The circumstances under which public attention was directed to these singular phenomena, are thus recorded:—"In the year 1751, two members of the Academy of Paris, Guettard and Malesherbes, on their return from Italy, where they had visited Vesuvius, and observed its productions, passed through Montelimart, a small town on the left bank of the Rhone, and having walked out to explore the neighbourhood, the pavement of the streets immediately attracted their attention. It is formed of short articulations of basaltic columns, planted perpendicularly in the ground, and resembles, in consequence, those ancient roads in the vicinity of Rome, which are paved with polygonal slabs of lava. Upon inquiry they learned that

* Geology of Central France.

these stones were brought from the rock upon which the castle of Rochemaure is built, on the opposite bank of the Rhone, and they were informed, moreover, that the mountains of the Vivarais abounded with similar rocks. This account determined the academicians to visit that province; and discovering every day fresh reason to believe in the volcanised nature of the mountains they traversed, they reached, step by step, the capital of Auvergne. Here all doubts on the subject ceased. The currents of lava, in the vicinity of Clermont, black and rugged as those of Vesuvius, descending uninterruptedly from conical hills of scoriæ, most of which present a regular crater, convinced them of the truth of their conjectures; and, delighted with the information thus acquired, M. Guettard, on his return to Paris, published an account of the discovery. His statement, however, was heard with doubt by a public little prepared for scientific investigation; and a Professor of Clermont having published an essay, in which he declared these appearances to be nothing more than the remains of forges and iron-works, undertaken by the Romans, who, in all half-civilised countries, are considered to be the authors of everything extraordinary or stupendous, the Professor gained more votaries than the naturalist, and the assertions of the philosopher were received with scepticism and distrust. The Professor should, however, rather have attributed these labours to the Gauls, the ancient inhabitants of Auvergne, who are mentioned by Cæsar as having possessed mines, and availed themselves of their skill, as miners, in the defence of the city of Avaricum." *

The attention of later observers having, however, been drawn to this region, and M. Desmaret having published his Memoirs on the origin of basalt, accompanied with maps of many of the lava-currents of Auvergne, all doubts were, at length, removed, and the true character of this singular region was fully and universally acknowledged.

The district which is the site of these volcanoes, is a vast plain, called *La Limagne d'Auvergne*, remarkable for its fertility, as is the case with all soils formed of volcanic detritus; it is enclosed, on the east and west, by two corresponding ranges of gneiss and granite; its average breadth

* Cæsar, lib. vii. c. 21.

being twenty miles, and its length between forty and fifty. The surface is formed of pebbles and boulders of granite and basalt, reposing on limestone; the river Allier flows through the district, over beds of this limestone, or siliceous sandstone, except where it has occasionally excavated a channel to the granitic foundation-rock. Hills composed of calcareous and alluvial deposits, which are scattered over the district, are supposed to be the relics of a more ancient plain, once existing at a higher elevation than the present, some of them being surmounted with basalt, others with limestone, which has protected and preserved them. On the western side of the plain the limestone disappears, and a plateau of granite rises 1600 feet above the valley of Clermont. This mass of granite supports a series of not less than seventy volcanic cones, varying in height from five hundred to a thousand feet, and forming a range nearly twenty miles in length, and two in breadth. The most remarkable of these ancient vents, are the Puy de Côme and the Puy de Montgy.

For a description of these in detail, as well as of the neighbouring volcanoes of the Vivarais, and the Cantal, we must refer to Mr. Scrope's work, and shall content ourselves with calling attention to one or two of the most remarkable features of this interesting district.*

Among the agencies of nature, volcanic action is one of the most awful and powerful. A force which melts up the solid materials of the earth, and ejects them as floods of lava over the surrounding districts, which lays waste the most fertile regions, overwhelms the fairest cities, and entombs them in its ashes, naturally arrests our attention. This tremendous power was most extensively developed in this region. When we contemplate not a single volcanic vent, but numbers of these comprised in a limited area, we recognise the vast scale on which this agency was exerted during the tertiary period. Having thus briefly alluded to these mightier manifestations of creative power, we shall now direct the attention of the student to some phenomena in the same region regarded as the most insignificant.

There is a little crustacean (*Cypris*), some species of which

* Sir C. Lyell's Principles of Geology contains a valuable epitome of the volcanic phenomena of Auvergne.

inhabit our ponds and ditches. The body of the animal is enclosed in two cases, like a mollusc within a bivalve shell (fig. 265), its principal organs of motion consisting of antennæ, and feet, which protrude from between the valves. These shields, it frequently sheds, and we may judge to what an extent, and during how long a period of time, these creatures continued to cast their shells in the waters of the lake, when we learn that beds of limestone, one hundred feet in thickness, are in an essential degree formed of the exuviæ of these crustaceans, which divide the limestone into laminæ, no thicker than the leaves of a book.

FIG. 265.—Fossil shell of Cypris, magnified.

A large and extinct species of caddis-worm, which abounded in the ancient lakes of Auvergne, was accustomed to cover its case with the shells of a small species of *Paludina*. Vast beds of the limestone of this region termed indusial are essentially composed of these remains. When, we consider that ten or twelve of these cases may be packed within the space of a cubic inch, and that single beds of this limestone may be traced over an area several miles in extent, we may form some idea of the countless numbers of insects and molluscs, whose remains have contributed to form this remarkable rock, and of the incalculable period of time required for its deposition.

These indusial limestones form but a portion of the strata of the district. The various beds present an alternate series of volcanic and lacustrine deposits, an accumulation of clays, sands, and breccias, beds of gypsum, and freshwater limestone, containing lacustrine and terrestrial organic remains, with intrusions of lava, scoriæ, and basalts, to an extent so enormous as to indicate no less than six successive eras of alternate activity and repose, each of vast duration, and tending, in the aggregate, immensely to increase the geological antiquity of these formations.

The beds of freshwater limestone contain, in addition to vegetable remains, and land and freshwater shells, teeth and bones of the *Palæotherium*, *Anoplotherium*, deer, ox, martin, dog, &c.; whilst in the overlying deposits of sand and diluvial gravel are embedded the teeth and bones of the elephant,

mastodon, hippopotamus, rhinoceros, tapir, horse, deer, ox, boar, hyæna, bear, dog, castor, cat, and hare.

The Abbé Croizet, some years since, formed an extensive collection of the fossils of this district, which was purchased by the French Government; and pursuing the same researches he has succeeded in forming a second assemblage of similar remains, which are now in the British Museum.

Erosive Force of Streams.—The power of running water to erode solid rocks, and to produce valleys by their currents, is most strikingly exemplified throughout the whole of this remarkable region. The erosive power of the water has been aided by the proneness of the volcanic rocks to decomposition. In some instances beds of lava have been corroded by the water, which has worn through a mass of rock 150 feet in height, and formed a channel in the granite beneath, since the lava first flowed into the valley. In another spot, a bed of basalt 160 feet high has been cut through by a mountain-stream. In the valley of Monpezat, the basalt has been similarly worn in more than one direction, by the powerful action of the rivers whose channels it had usurped; an idea of its present disposition, and the beautiful columnar ranges discovered by this excavation, may be formed from the following sketch, fig. 266.*

Tertiary Strata of other Regions.—Similar extinct volcanoes exist in Hungary, Spain, and other parts of Europe, which, with the salt mines of Gallicia, are referred to this epoch. Tertiary strata are found in North and South America, in India and Australia, and M. Boué has lately discovered a district in Asia Minor, in the vicinity of Smyrna, called the Κατακεκαυμένη, or Burnt-up region, comprising the ancient Sardis and Philadelphia, which presents a close resemblance to Auvergne. In each country are extensive lacustrine formations, cones of scoriæ, with currents of lava, and occasionally continuous streams and thick beds of that substance, worn through by the action of running water.

Fossil Infusoria.—In strata of this period occurs the siliceous stone called Tripoli, which is also found at Bilin in Bohemia. This rock is almost entirely composed of the

* From Mr. Scrope's Central France.

skeletons or cases of Infusoria. A stratum twenty-eight feet in thickness, interposed between the eocene and miocene stages in North America, and extending over a considerable

FIG. 266.

area, the city of Richmond, in Virginia, being built on it, is composed of fossil infusoria, chiefly of the genera *Navicula* and *Gaillonella.* The remarkable composition of these rocks tends strongly to confirm the supposition of the organic origin of many deposits.

We have thus brought to a close our remarks on this instructive period of the earth's history. Our observations, however incomplete, when compared with the magnitude of the subject, are more in detail than our limits will permit us to devote to the other formations, as many of the phenomena observable in the tertiary are repeated in the older rocks; the explanation of these, in the first instance, will obviate the necessity of their repetition in succeeding chapters.

The deposition of the tertiary strata in depressions of the chalk is demonstrated by the basins of London, Hampshire, and Paris; the changes in the level of land and sea are proved by the alternations of fresh-water and marine strata:

the existence of extensive lakes is shown by the lacustrine formations of our southern coast and the continent of Europe: the development of volcanic agency is evident from the structure and physical geography of Auvergne; while a change of climate is evinced by the appearance of crocodiles and chelonians like those of the modern epoch, the creation of mammalia, and the approximation of the genera of shells to living forms; the gradual introduction of existing plants, and the more European character of the fauna and flora of the tertiary when compared with those of the secondary epoch.

EXERCISES

ON THE TERTIARY SYSTEM OF DEPOSITS.

1. Explain the meaning of the term tertiary.
2. Describe the geographical distribution of the strata appertaining to these formations.
3. Name the chief authors and the principal collections of organic remains.
4. Describe the characteristic features of these deposits.
5. Repeat the classification proposed by Sir C. Lyell, the names of the divisions, and the relative proportions of shells identical with existing forms which determine them.
6. Name the most important localities of these beds in this country.
7. Mention the principal characteristic shells of the crag, and London basin.
8. Describe the basin of Paris, its extent, and distinctive organic remains.
9. Name the chief features of the geology of Auvergne, its physical geography, alternation of deposits, fossil remains, and the changes and revolutions inferred from its varied phenomena.
10. Mention the other deposits of this group occurring in France.
11. Name the fossil remains of Monte Bolca.
12. Name the localities in which similar phenomena are observed in Europe.
13. Mention the latest discoveries made with reference to this period of the earth's history in other regions.

CHAPTER XII.

THE CRETACEOUS GROUP.

Chalk, Craie of French; Kreide of German Authors; Chalk-Marl, English; Craie-Tufau, French; Kreide-Mergel, German; Greensand, English: Glauconie-Crayeuse-Sableuse, French; Chloritische Kreide, Grünsand, German.

MUSEUMS:—Geological Society, Collection of Dr. Mantell in the British Museum; that of Mr. Bowerbank, Mr. Saul, Mr. Dixon, of Worthing, Mr. Purdue, and many Private Collections in the Southern and Eastern Counties, Yorkshire, &c. &c.

AUTHORS:—Lyell, Mantell, Dixon, Fitton, Phillips, Woodward, Boblaye, Virlet, D'Orbigny, Roemer, Reuss.

CHARACTERISTICS:—First of the Secondary Formations; Marine; the Bed of an Ancient Sea, Containing Marine Plants, Corals, Shells, Fishes and Reptiles.

THE chalk constitutes the boundary of the secondary rocks; it formed the bed of a primeval ocean, of great extent, whose spoils have largely contributed to the formation of our existing islands and continents.

SUBDIVISION.—The following Table exhibits the different stages of this period and their foreign equivalents:—

	English Authors.	French Authors.	Roemer.	D'Orbigny.
Upper.	Chalk with flints.	Craie.	Obere Kreide.	L'étage Danien.
	Chalk without flints.	———	Untere Kreide.	„ Sènonien.
	Chalk marl.	Craie Tufau.	Planer.	„ Turonien.
Lower.	Upper greensand.	Glauconie Crayeuse.	Grünsand.	„ Cênomanien.
	Gault.	———	Galt.	„ Albien.
	Lowergreensand.	Glauconie Sableuse.	Quader.	„ Aptien.
			Hilsconglomerat.	„ Nèocomien.

The white chalk is nearly a pure carbonate of lime, and contains, in some localities, an immense profusion of microscopic shells and the débris of radiated animals; it is divided into flinty chalk and chalk without flints. These siliceous nodules indicate the plane of stratification of the beds. In some parts of Yorkshire the lower chalk contains flints, and the same fact is observed in the lower chalk at Havre: the chalk marl consists of a greyish, earthy, marly chalk, sometimes indurated.

The upper greensand, in some localities, as at Black Down, consists of a sharp siliceous sand; in others, of a marly calcareous sand, with green grains and mica; the celebrated firestone of Mertsham is of this character, and it presents similar lithological features in the Isle of Wight; the gault is a dark blue tenacious clay, with indurated concretions; in some localities, as at Folkestone, the nacreous layer of its fossil shells is beautifully preserved. The lower greensand consists of an alternation of ferruginous sands, intercalated with beds of clay and clayey sand, sometimes containing bands of limestone and regular seams of chert; it attains, in the Isle of Wight, a thickness of 808 feet, and is divided into three subdivisions by Dr. Fitton: our table shows that the lower greensand is the equivalent of the "*Terrain Néocomien*" of the French geologists, MM. Cornuel and Leymerie, which is largely developed in various parts of the Continent, especially near Neufchâtel.* It was supposed that this system formed the marine equivalent of the wealden, but subsequent researches have shown that the opinion is incorrect. The neocomian fossils belong to the same era, and many of the species are identical with those of the lower greensand. Beds of this character, containing similar shells, occur in Surrey and Kent, and at Atherfield, in the Isle of Wight; as these unquestionably belong to the lower greensand, it results that the hypothesis which would place these rocks, as they exist on the Continent, as the equivalent of the wealden formation, must be abandoned; in all probability the neocomian strata will be found to be a larger development of a portion of our lower greensand group.

The fossils of the cretaceous system consist of marine

* From whence the term *Néocomien* is derived.

plants, sponges, corals, echinoderms, belemnites, ammonites, nautilites, fishes, reptiles, and other marine exuviæ, with occasional instances of wood and plants drifted from the land, the whole presenting forms of life specifically distinct from those occurring in the overlying beds; no species discovered in the chalk being identical with those of the tertiary deposits. They form the spoils of a primeval sea, which rivalled in extent the mighty oceans of the southern hemisphere at the present day; as the chalk group extends over portions of the British islands, various parts of France, Germany, Denmark, Sweden, Russia, and North America.

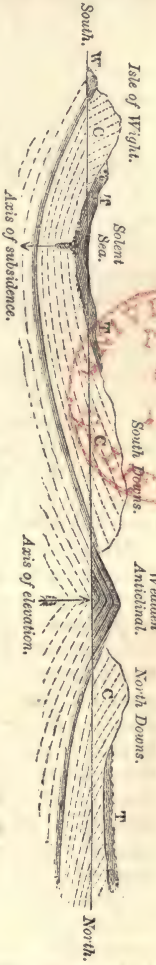


Fig. 267.—Ideal Section from London to the Southern Coast of the Isle of Wight.

T. Tertiary. C. Chalk. W. Wealden.

This ideal section (fig. 267) from London to the Isle of Wight, shows the relative position of the tertiary cretaceous and wealden groups, with the axis of elevation and subsidence observed in the region through which the line of the section is supposed to pass.

On the coast of Dorset, and in the Isle of Wight, the chalk strata are sometimes vertical; the line of disturbance which upheaved the tertiary beds of Whitecliff and Alum bays produced this position of the chalk rocks.

It was long ago observed by Sir H. Englefield, that the flints in the vertical beds of chalk are all fractured and fall to pieces when taken out of their matrix; proving the suddenness of the convulsion which shattered them. The beautiful section (fig. 268) of Ballard Head shows the junction of vertical and contorted chalk strata.

Origin of the Chalk and Flint.—The idea which

prevailed, up to a very recent period, as to the origin of chalk and flint was this:—It was supposed that thermal

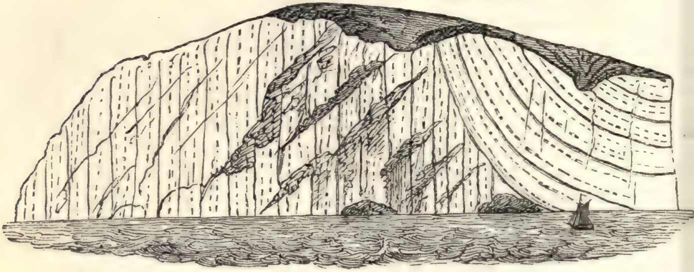


FIG. 268.—Junction of vertical and contorted Chalk Strata at Ballard Head, Dorsetshire. The cliff is 352 feet high; the down, 584 feet.

waters, charged with calcareous and siliceous matter, were poured into the ocean, and that, on mingling with the colder element, the calcareous and siliceous substances were precipitated in a solid state, and, separating by the laws of chemical affinity, deposited the chalk and flint.

Many distinguished observers, however, had ascribed these substances to a different cause. A century ago, Linnæus declared his conviction that calcareous strata were of animal origin, and the recent observations of microscopic observers have tended to confirm the opinion of this great naturalist. Chalk, when reduced to powder, and appearing like mere grains of dust to the eye, consists, in fact, of well-preserved fossils of the beautiful forms depicted in figures 186 and 187; but these specimens are really gigantic, when compared with the smaller extinct forms of life which are contained within them; the chambers of these foraminifera being filled with thousands of well-preserved infusoria, whose skeletons abound in the cretaceous rocks. We have only to brush a piece of chalk in water, dry the particles thus obtained, and examine the residuum with the microscope, and we shall find it consisting of minute shells, corals, or portions of these.

As many other rocks are found on microscopic examina-

tion to present similar appearances, it is considered that not only is the chalk of organic origin, but that a large proportion of the sedimentary strata are derived from the same source, and have passed through the great laboratory of life. This opinion of the vital origin of calcareous strata derives considerable confirmation from the operations of nature. Not only is it found that the coral polyp is rearing reefs and islands from the bosom of the deep, and uniting them into continents; but on the shores of many of the West India Islands, especially the Bermudas, it is observed, that on the coral formations being exposed to the abrading power of the waves, the sea becomes loaded with calcareous matter, a considerable portion of which is drifted to the shores in the state of fine sand, which, being wafted inland by the winds, becomes consolidated by the percolation of water, and the infiltration of carbonate of lime in solution; so that a white calcareous stone is formed, of various degrees of hardness, from a coarse friable limestone, to the compact rock employed in constructing the fortifications of the island.

Lieutenant Nelson* states that the whole of these islands, comprising a hundred and fifty in number, may be called organic formations, as they present one mass of animal remains, in various stages of disintegration. From the most compact rock to the loose sand of the shore, the materials are fragments of shells, corals, &c. He therefore ascribes the Bermuda chalk to animal origin, and suggests the extreme probability, that the chalk of Europe was produced by similar causes. The skeletons of Guadaloupe have been mentioned as being embedded in a limestone rock of the same modern character; and it is impossible to conceive a more perfect analogy than is here presented, between the operations of nature at the present moment, and those exhibited in the primeval eras of the earth's history. A series of microscopic observations, has shown that both the tabular and nodular masses of chalk flints are due to the presence of sponges, and that the flints which fill up the cavities of shells and urchins are probably owing to a similar cause.

FOSSILS OF THE CHALK.—These are extremely numerous,

* Memoir on the Geological Formation of the Bermudas.—Transactions of the Geological Society, vol. v. p. 115.

and are entirely marine, consisting of sponges, corals, echinoderms, shells, crustacea, fishes, and reptiles. Flints are so constantly associated with organic substances that it is scarcely possible to meet with one which does not contain a sponge, urchin, or shell, or the impression of one or more of these organisms. The choanite, which forms the nucleus of many flints, and produces the beautiful markings on the cut surfaces of polished pebbles, is a common zoophyte of the white chalk.

The Echinodermata were extremely abundant in the cretaceous seas. The genera, *Marsupites*, *Ananchytes*, *Spatangus*, *Echinus*, *Micraster*, *Cyphosoma*, *Salenia*, and *Cidaris* greatly prevailed. Figures of the most common forms of this sub-kingdom have been described and figured in our Chapter on Palæontology. See figs. 157, 158, 161.

SHELLS OF THE CHALK.—The accompanying figures represent several of the most common cretaceous fossil shells:—

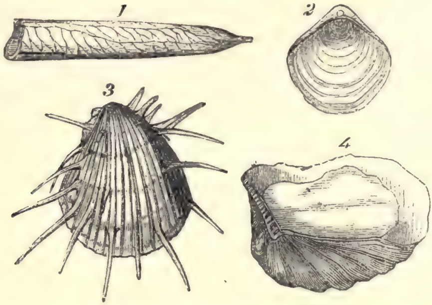


FIG. 269.—1. Belemnites Listeri. 2. Terebratula carnea. 3. Lima spinosa. 4. Inoceramus Cuvieri.

Of the above, the *Inoceramus* is of a thin, fibrous structure; the *Lima spinosa* is very characteristic of the upper chalk; the *Terebratula* is a well-known fossil, which, originating in the earliest formations, and being profusely distributed through the succeeding stages, has dwindled down to a few species at the present day; the *Belemnite*

has been discovered in the oolites, with the external sheath, the conical-chambered shell, the ink-bag, and the bone; the ink, though fossilised, retaining its pigmentary property.

The following figure (270) represents several of the most characteristic fossil shells which are special to the beds that underlie the white chalk,—the marl, the gault, and the upper greensand:—

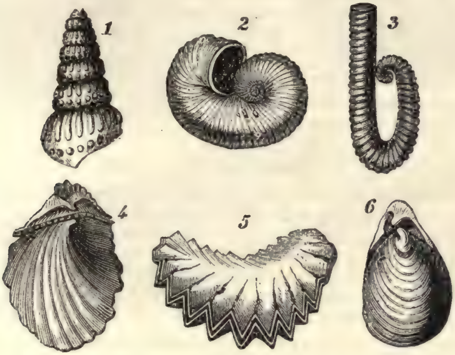


FIG. 270.—1. Turrilites costatus (Chalk Marl). 2. Scaphites striatus (C. Marl). 3. Hamites (C. Marl). 4. Inoceramus sulcatus (Gault). 5. Ostrea carinata (Greensand). 6. Inoceramus concentricus.

Dr. Fitton has published * an admirable memoir on the Lower Greensand or neocomian strata of Atherfield. The beds, 808 feet in thickness, contain 160 species of fossils, the range and distribution of which the author has exhibited in a tabular form; it is impossible to employ terms of commendation too high in referring to this valuable memoir, which, for clearness and accuracy, is a model for all geologists: we give from Dr. Mantell's "Isle of Wight" the annexed plates of the most characteristic shells of the lower greensand, or neocomian strata.

* Geological Journal, vol. iii., p. 289.

DESCRIPTION OF FIG. 271.

1. Corbis corrugata, from the sand-rock, Atherfield: the figure is one-half the size in linear dimensions of the original.
2. Trigonia caudata. from the sand-rock, Atherfield.
3. Gervillia anceps, from the Cracker Rocks, Atherfield; *a*, denotes the markings of the hinge, which are seen in consequence of the valves being slightly displaced. It is represented half the size linear of the original. These shells are often much larger, and more elongated than in the figure.
4. Venus striato-costata; a small shell, common in the Cracker Rocks at Atherfield the figure is twice the size of the original in linear dimensions.
5. Arca Raulini, from the sand-rock, Atherfield.
6. Perna Mulleti, from the lower beds of sand in conjunction with the wealden, Sandown Bay; the figure is but half the size of the original: *a*, the structure of the hinge; by comparing this figure with *a*, No. 3, the difference of the hinge in the genera Perna and Gervillia will be recognised. This large and remarkable shell is highly characteristic of the lower beds of the greensand.
7. Venus parva, from Shanklin Cliff.

DESCRIPTION OF FIG. 272

1. Thetis minor, from the ferruginous sand-rock at the base of Shanklin Cliff.
2. Another view of the same, to show the beaks and hinge-line.
3. Gryphea sinuata, represented one-fourth the natural size; it is often found much larger. From the greensand at Shanklin, Ventnor. Sandown, &c.
4. Tornatella albensis, from the Cracker Rocks, Atherfield.
5. Terebratula sella; an abundant shell in the sand at Atherfield.
6. Nucula scapha, from the sand-rock, Atherfield.

The three following shells are embedded in a fragment of the Cracker Rock, from Atherfield.

7. Natica rotundata.
8. Pterocera retusa.
9. Rostellaria Robinaldini.
10. Cerithium turriculatum, from Atherfield.
11. Ancyloceras gigas, from Atherfield. The figure is but one-third the size, linear, of the original.

This fossil is often found two feet in length, associated with Ammonites equally gigantic.

FISHES OF THE CHALK.—The most interesting remains, exhumed from the Sussex chalk, consist of numerous admirably preserved fishes, which have furnished subjects for a portion of the work of Professor Agassiz.* We select *Osmeroides Mantellii*, as an illustration (fig. 273.):

* The following is the eulogy of Agassiz on this highly interesting collection:—" Tout le monde sait que le Musée de M. le Dr. Mantell est une collection classique pour la craie et la formation Veldienne. Les soins minutieux que M. Mantell a donné, depuis bien des années, à ces fossiles, les ont rendus plus parfaits que tous ceux des autres musées; car, souvent il est

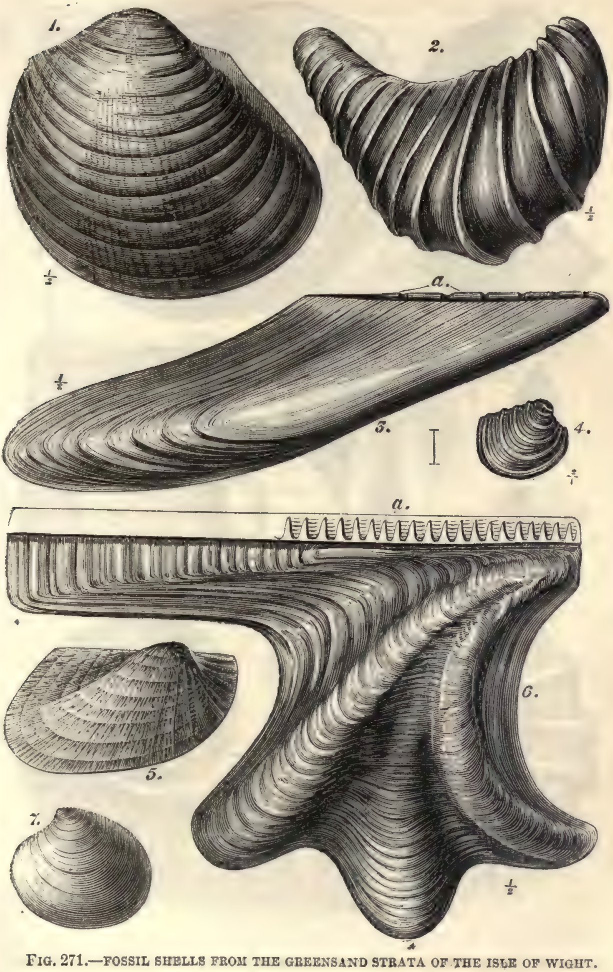


FIG. 271.—FOSSIL SHELLS FROM THE GREENSAND STRATA OF THE ISLE OF WIGHT.

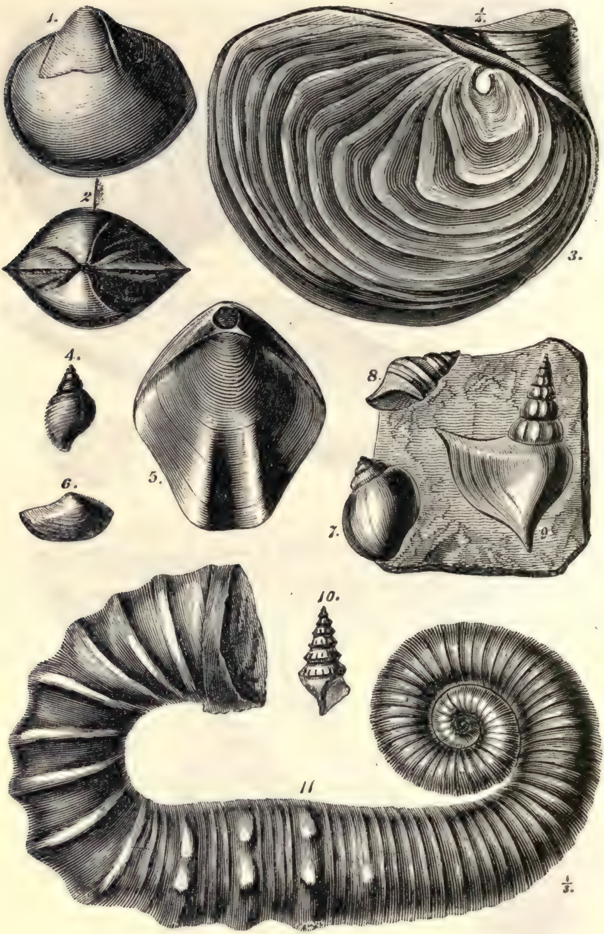


FIG. 272.—FOSSIL SHELLS FROM THE GREENSAND STRATA OF THE ISLE OF WIGHT.

The fish here depicted has the mouth open, the gills and the fins extended, while the body is uncompressed; from which it is inferred that the creature must have been living, moving, and breathing, when it was surrounded by the chalk.

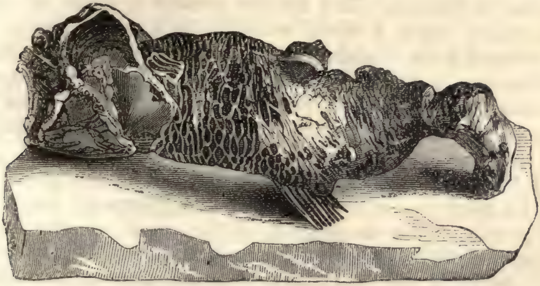


FIG. 273.—Osmeroides Mantellii.

THE MOSASAURUS.—The chalk of Kent and Sussex have likewise afforded teeth, a jaw, and vertebræ, of the mosasaurus, or lizard of the Meuse, a reptile which excited very considerable interest at the period of its discovery. It was a marine saurian, intermediate between the monitor and iguana; it is supposed to have been twenty-five feet in length, and to have possessed a tail, which became flat, like an oar, at some distance from the body, and formed a powerful instrument of propulsion.

In the greensand of the vicinity of Hythe, the remains of a reptile of colossal size have been discovered, which, from the teeth exhibiting peculiar fold-like markings, has been described under the name of the *Polyptychodon*.*

parvenu à les détacher, entièrement, de la roche dans laquelle ils se trouvaient; ou du moins, à les produire en relief, en détachant toutes les matières solides qui recouvraient les parties les mieux conservées de l'animal."

The late F. Dixon, Esq., of Worthing, has formed a splendid collection of the fossils of the chalk, comprising many rare and unique specimens, among which are examples of the *Hippurites* and *Sphærulites,* which, though not unfrequent in the cretaceous rocks of the Pyrenees and other parts of the Continent, are most rare in the English chalk. These form the subject of his beautiful monograph on the Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex.

* Now in the British Museum. See Proceedings of the Geological Society, part iii., p. 449.

Denudation of the Chalk.—This brief account of the cretaceous deposits may be appropriately closed by a few remarks on the denudation of the chalk; that is, its removal from the valleys of the weald, which lie between the North and South Downs. The former present a range of chalk hills, which have a steep escarpment towards the south, and extend from Godalming, through Godstone, into Kent, terminating in the cliffs of Dover. The latter have a corresponding escarpment towards the north, and form the promontory of Beachy Head, traverse the county of Sussex east and west, and pass by Hampshire into Surrey.

At the base of these escarpments, the upper greensand and the gault are found resting on the valleys of the weald. The proofs of the denudation of the chalk, consist in the appearance of the strata in these escarpments. They terminate abruptly, and, it is evident, must once have extended much further, since they offer precisely such appearances as would be presented by the cutting of strata which were previously continuous. Proofs no less conclusive are afforded by the conformation of the wealden beds themselves: the forest-ridge, which traverses the district in a direction nearly east and west, presents a perfect anticlinal axis (fig. 267), from which the strata diverge on each side towards the chalk downs, affording the most convincing proof of the elevation of the wealden, and the subsequent removal of the chalk and other beds, which may have been deposited upon them. It is conjectured, that the tertiary strata once extended over the chalk which reposed on the wealden, and covered the whole area of the south-east of England. This supposition receives some confirmation from the outliers of the tertiary beds, occurring at Castle Hill, Newhaven, and near Seaford.

In reviewing the characters of the cretaceous group, we have evidence that these varied strata are the mineralised bed of an extensive ocean, which abounded in the usual forms of marine organic life, as algæ, sponges, corals, shells, crustacea, fishes, and reptiles. These forms are all specifically distinct from those which are discovered in the tertiary strata: in many instances, the genus—in all, the species—became extinct with the close of the cretaceous period. It affords a striking illustration of creative powor, that of the

hundreds of species which composed the Fauna and the Flora of the cretaceous group, not one species passed into the succeeding epoch.

EXERCISES

ON THE CHALK FORMATION.

1. Describe the geographical distribution of the chalk.
2. State the distinctive features of this formation.
3. Enumerate the separate divisions of these strata in this country, and the mineral character, distinguishing features, and general characteristics of each.
4. State the opinions heretofore entertained of the origin of chalk and flint.
5. Explain those of later observers.
6. Describe the physical geography of the formation, and point out the area of the denudation of the chalk.
7. Name the remarkable fossil remains discovered in this formation.

CHAPTER XIII.

THE WEALDEN GROUP.

Wealden formation of English; Formation Veldienne of French; Wälderthongebilde of the German Authors.

MUSEUMS:—The Mantellian Collection, now in the British Museum; those of the Marchioness of Hastings; Mr. Holmes, of Horsham; Mr. Bowerbank, Mr. Saull, and some private Cabinets in Sussex.

AUTHORS:—Mantell, Fitton, Murchison, Martin, Hopkins, Dunker, and Meyer.

CHARACTERISTICS:—The Fluviatile Character of its Fossil Remains being the Spoils of the River and the Land.

English Authors.	French Authors.	German Authors.
1. Weald Clay.	Argile Veldienne.	Wälderthon.
2. Hastings Sands.	Sable ferrugineux.	Hastingssandsteine.
3. Ashburnham Beds. }	Calcaire Lumachelle.	Ashburnham Schichten.
4. Purbeck Beds. }	Purbeckien.	——

THERE is one feature which serves to identify this group, and invests it with peculiar interest. It is a fresh-water deposit, the only one of that character, with the exception of the coal, which exists in the vast range of the secondary rocks, and affording, with it, almost the only evidence we possess of the existence of the ancient land; its organic remains consisting of fluviatile plants, shells, fishes, and reptiles.

FORMER OPINION OF THESE DEPOSITS.—The strata which we are about to describe, are most fully developed between the North and South Downs, forming the district denominated the weald; from *Wald*, a wood, the whole tract having at a former period been occupied by extensive forests. In consequence of being exposed between two ranges of chalk-hills, the wealden was formerly regarded as appertaining to that group, and, from being chiefly composed of clays, sands, and sandstones, was believed to

belong to the lower greensand formation. At a very early period of his researches, Dr. Mantell observed that the fossils collected from these deposits were wholly of a fluviatile character. Instead of the sea-weeds, sponges, corals, shells, and the other marine exuviæ found in the chalk, he discovered the leaves, branches, and stems of plants, with bones of reptiles, and fresh-water shells. The stems were deprived of their branches, the branches were denuded of their leaves, while the animal remains bore similar proofs of maceration and transport, arising from fluviatile action. Pursuing these inquiries, Dr. Mantell determined the true character of the strata, and established the fact, that instead of being of marine, they were of fresh-water origin, and, from the evidence of drift, arrived at the conclusion that this district formed the delta of an ancient river where it poured its waters into the sea.

The evidence of so unexpected a fact as the intercalation of a great fresh-water formation between the chalk and the oolites was, at first, received with much doubt; but subsequent investigations proved the correctness of the original observations. The relative position of the beds in the Isle of Wight especially is unequivocal. The lower greensand is seen reposing conformably on the wealden. At their junction near Atherfield Point, we have removed a mass of rock about a foot in thickness, the upper half of which contained *in situ* the marine shells of the lower greensand, whilst in the lower half of the same we found the fluviatile shells of the wealden. In the Vale of Wardour, the Purbeck beds are seen reposing conformably on the upper stages of the oolites.

The following subdivisions, from Dr. Mantell's Geology of the S.E. of England, exhibit the wealden stages of Kent and Sussex:—

1. WEALD CLAY, average thickness 140 to 200 feet.

Character.	Fossils.	Localities.
Stiff Clay, of various shades, of blue and brown; with subordinate beds of limestone, sand, and *Septaria*.	Paludina, Cypris, Cyrena, and Bones of Reptiles rarely; Scales and Bones of Fishes.	The Wealds of Sussex, Surrey, and Kent; forming the vale between the Downs and the Forest Ridge.

2. Hastings Sands, average thickness 400 to 500 feet.

A. Horsted Sand.

Grey, white, ferruginous, and fawn-coloured sands, and friable sandstone, with small portions of lignite.	Traces of carbonised Vegetables.	Little Horsted, Uckfield, Framfield, Bexhill, Chailey, Fletching, Eridge Park, Tunbridge Wells, &c.

B. Strata of Tilgate Forest.

Sand and friable sandstone of various shades, of green, yellow, and ferruginous. Tilgate stone, fine, compact, bluish or greenish grey Grit, in lenticular masses; surface often covered with mammillary concretions; lower beds frequently conglomeritic, and containing quartz pebbles.	Ferns, stems of Vegetables, bones of Saurian Reptiles, Birds, Turtles, Fishes, and Shells of the genera Unio, Cyclas, Cyrena, Paludina.	Loxwood, Horsham, Tilgate, and St. Leonard's Forests; Chailey, Hastings, Rye, Winchelsea.
Clay or marl, of a bluish grey colour, alternating with sand, sandstone, and shale.	Bones and Shells rare; Ferns, and stems of Vegetables.	Tunbridge Wells.

C. Worth Sandstone.

White and yellow friable sandstone and sand.	Ferns, Arundinaceæ, and Lignite.	Worth, St. Clement's Cave, Hastings, &c.

3. Ashburnham Beds.

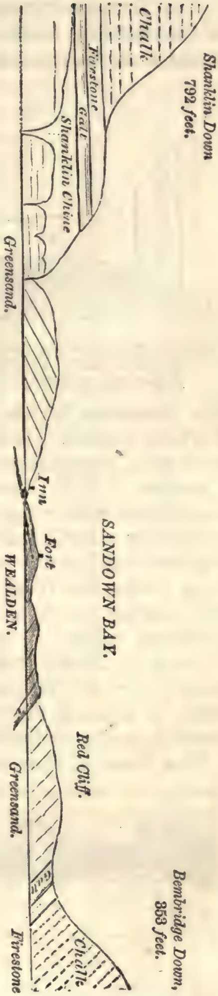
A series of highly-ferruginous sands, alternating with clay and shale.	Ferns and Lignite.	Hastings Cliffs, near Buxted, West Hothley, Crawley, &c.
Shelly limestone, alternating with sandstone, shale, and marl, and concretional masses of grit.	*Cypris*, shells of the genera *Cyclas*, *Cyrena*, Lignite, carbonised Vegetables.	Archers Wood, Pounceford, Burwash, Hurst Green, Eason's Green.

The wealden is very well developed and exposed in the Isle of Wight, and forms the cliffs between Atherfield Point and Compton Bay, and also appears at Sandown Bay. The following section (fig. 274*) shows the relative position of the wealden and chalk with the anticlinal axis at Sandown.

* Dr. Fitton's Memoir on the Strata below the Chalk.

The Purbeck beds, and their overlying sands, are well seen in the coast sections of the south-western shores of the Isle of Purbeck. The relative position of these beds is exhibited in fig. 275.

GEOGRAPHICAL DISTRIBUTION.—The wealden extends from Horsham to Hastings, where it dips beneath the sea, forms the bed of the English Channel, and re-appears in the valley of Braye, in the province of the Boulonnais; thus occupying an area of 200 miles from west to east, and 220 from north-west to south-east, the total thickness being about 2,000 feet. Strata resembling the weald clay and Hastings sand have been discovered by M. Roemer, in Germany, where they occur near Helmsted, and extend westward from Hanover, by Minden, to Iburg and Rheine, near Münster, in Westphalia, abounding in seams of good coal, from one to three feet thick. Deposits of like character occur in the Isle of Bornholm; and, with the progress of geological investigation, it is probable that other instances will be discovered, since the land which gave rise to the river of the weald was, doubtless, drained by others flowing in different directions.



W. Fig. 274.—Section from Shanklin to Bembridge Down, across Sandown Bay; 4½ miles E.

THE ISLE OF PURBECK.— On the western shore of the Isle of Purbeck, the chalk is raised to a vertical position, and the wealden beds beneath are clearly displayed. (Fig. 275.)

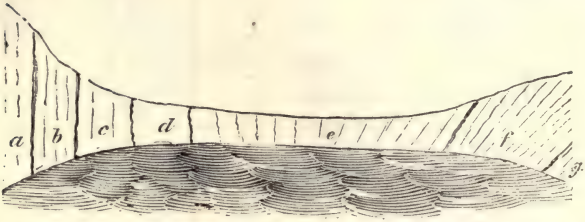


FIG. 275.—Plan of the Stratification of the Coves on the South-western Coast of the Isle of Purbeck. *a*, Chalk; *b*, Chalk-marl; *c*, Firestone; *d*, Gault; *e*, Wealden; *f*, Purbeck; *g*, Portland Oolite.

The limestone which underlies the chalk is well known as Purbeck marble. It is composed of small freshwater shells, *Paludinæ*, intermixed with the minute shelly coverings of *Cyprides*. This limestone was so extensively employed during the middle ages for ecclesiastical edifices, that there is scarcely a cathedral or church of importance in which the Purbeck marble was not used for decoration. This section, from Durlstone Head to Ballard Downs (fig. 277), exhibits the relative position of the strata from the chalk to the Portland oolite.

ISLE OF PORTLAND.—The Island of Portland is a bold promontory off Weymouth, sloping gradually towards the land: it is about four miles and a half in length, and two in breadth, and is united to the mainland by the Chesil beach.

The base of the island consists of Kimmeridge clay,

FIG. 276.—Section of the Isle of Portland, Dorset.

and the oolitic limestone, which supplies the celebrated

Portland stone for building, on which rest the lowest fresh-water beds, and a mass of bituminous earth, called the "dirt-bed," which is an ancient vegetable soil, containing numerous trunks of fossil trees, standing erect at a height of from one to three feet, with their summits jagged, as if they had been broken off by a hurricane. (Fig. 276.)

They are placed at the same distance from each other as trees usually occupy in a forest, and have their roots attached; showing that they now occupy the spot on which they lived and flourished.

The same bed of earth contains many remains of *Cycadeæ*, allied to the recent *Cycas* and *Zamia*. From their rounded shape, they are called birds' nests by the workmen. (Fig. 279.)

The "dirt-bed" can also be traced on the mainland, being seen in the same relative position in the cliffs of Lulworth Cove, on the coast of Dorsetshire, where, however, the strata having been inclined to an angle of 45°, the dirt-bed, with its fossil trees, is inclined with them; presenting the most convincing evidence of the disturbance of strata, and a change in the position of beds originally horizontal, since it is obvious that the trees must have grown erect, and subsequently have been inclined with the bed in which they grew. Traces of the dirt-bed have been observed in Oxfordshire, and likewise in the cliffs of the Boulonnois, on the French coast.

It has been ascertained that the forest of the dirt-bed was not the earliest vegetation of this locality. Two beds of carbonaceous clay, one of them containing *Cycadeæ* in an erect position, have been discovered below it, and one above it; which fact, with others furnished by the organic

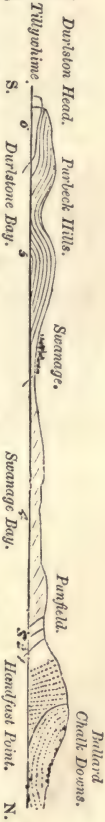


FIG. 277.—Section from Ballard Down to Durlstone Head, across Swanage Bay; the distance about three miles.
1. Firestone. 2. Gault. 3. Greensand. 4. Wealden. 5. Purbeck Strata. 6. Portland Oolite.

contents of the different beds, implies that many changes of condition took place during the deposition of the Purbeck beds. Professor E. Forbes has recently examined the organic remains of the three members of the Purbeck group,

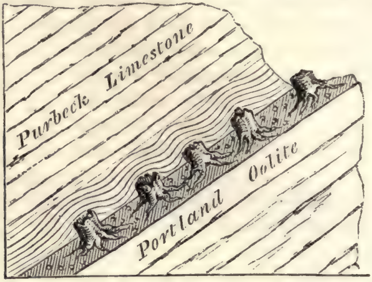


Fig. 278.—Section in a Cliff east of Dulworth Cove, Dorset.

displayed at Meup's Bay, Dorset, in a vertical section of 155 feet. To our previous information he has added some important facts; the Professor found that the upper, middle, and lower Purbecks, are each marked by peculiar species of organic remains; these, again, being different from the fossils of the Hastings sand and weald clay.*

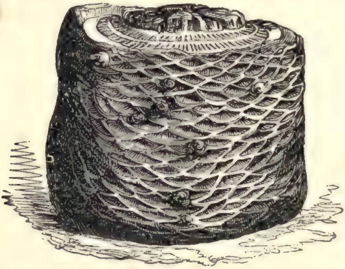


Fig. 279.—Mantellia nidiformis. Brongniart.

Upper Series.—The highest of the three divisions is purely a fresh-water deposit, about 50 feet in thickness,

* Professor E. Forbes, on the Dorsetshire Purbecks. See also Sir C. Lyell's Manual (third edition) for much interesting matter on this subject.

containing *Paludina*, *Physa*, *Lymnæa*, *Planorbis*, *Valvata*, *Cyclas*, and *Unio*, with the shields of cyprides, and remains of fishes.

Middle Series.—Consist of 30 feet of strata, deposited under changing conditions; the uppermost beds are of fresh-water limestone, with cyprides, turtles, and fishes of different species from those found in the upper series. Below the limestone are brackish water beds full of *Cyrena*, and traversed by seams of *Corbulæ* and *Melaniæ*. These are based on a marine deposit containing *Pecten*, *Modiola*, *Avicula*, *Thracia*, of new species. Below this, again, come limestones and shales, partly of brackish and partly of fresh-water origin, containing fishes of the genera *Lepidotus* and *Microdon*, and a reptile called *Macrorhyncus*. Immediately below is the "Cinder-bed," about 12 feet in thickness, formed of a vast accumulation of *Ostrea distorta*, *Perna*, and a new species of *Hemicidaris*, an urchin which is chiefly confined to the oolites. Below the "Cinder-bed," fresh-water strata again occur in many places filled with species of *Cypris*, *Valvata*, *Paludina*, *Planorbis*, *Lymnæa*, *Physa*, and *Cyclas*, with seeds of Charæ, distinct from those found in the beds above: beneath these fluviatile beds thin bands of greenish shales, with marine shells and impressions of leaves like those of a large *Zostera*, form the basement of the middle division.

Lower Series.—Beneath the marine bed just described, fresh-water marls occur, containing *Cypris*, *Valvata*, and *Lymnæa*, of species different from those of the middle division; this is the beginning of the lower series, which is about 80 feet in thickness. Below the marls are 30 feet of brackish water beds, with *Serpula*, *Rissoa*, and *Cardium*, together with *Cypris*; the "dirt-bed," with the roots and stools of *Cycadeæ*, underlies these marls, resting upon the lowest fresh-water limestone, a rock about 8 feet thick, containing *Cyclades*, *Valvata*, and *Lymnæa*, of the same species as those of the uppermost part of the lower series. This limestone rock rests upon the superior beds of the Portland stone, which is purely marine, and between which and the Purbecks there is no passage.

The following table * will enable the reader to understand

* Sir C. Lyell's Elements, Third Edition, page 235.

the changing conditions under which the strata were formed from the lower greensand to the Portland oolite inclusive, on the south-east coast of England:—

1. Marine	Lower Greensand	6. Freshwater, Brackish, Land, Freshwater, Land (dirt-bed), Freshwater, Land, Freshwater, Land, Freshwater	Lower Purbeck
2. Freshwater	Weald Clay	7. Marine	Portland Stone
3. Freshwater, Brackish, Freshwater	Hastings Sand		
4. Freshwater	Upper Purbeck		
5. Freshwater, Brackish, Marine, Brackish, Marine, Freshwater, Marine	Middle Purbeck		

The causes, says Professor Forbes, "that led to a complete change of life, three times, during the deposition of these freshwater and brackish strata, must be sought for not simply in either a rapid or a sudden change of their area into land or sea, but in the great lapse of time which intervened between the epochs of the deposition, at certain periods during their formation." It is interesting to find in the Purbeck beds, changes of condition of a similar character to those which we have described in the eocene strata of the north-west coast of the Isle of Wight,* where freshwater, brackish, and marine beds in like manner succeed each other, and are characterised by corresponding changes in their organic contents—changes which must have required long periods of time for their fulfilment.

WEALDEN STRATA OF THE ISLE OF WIGHT. — The wealden beds are extensively developed at the south side of the island, and constitute the foundation-rock of Sandown, Brook, and Brixton Bays. Fig. 281 is a coast section of the Isle of Wight from Blackgang to Afton Down, showing the relative position of the wealden and lower greensand with the western anticlinal axis of the island, which passes through Brook Point. The beds are observed to dip to the east and west at the point. This locality is likewise remarkable for the fossil forest of the wealden, which lies prostrate on the strand at low-water mark. The trunks of

* Dr. Wright: Annals of Nat. Hist., vol. vii.

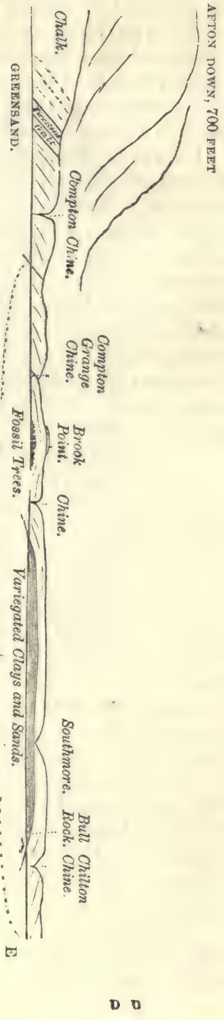


FIG. 280.—THE SECTION OF THE STRATA EXPOSED ON THE SOUTH COAST, FROM THE FOOT OF AFTON DOWN TO GRANGE CHINE.

(The distance about 4½ miles.)

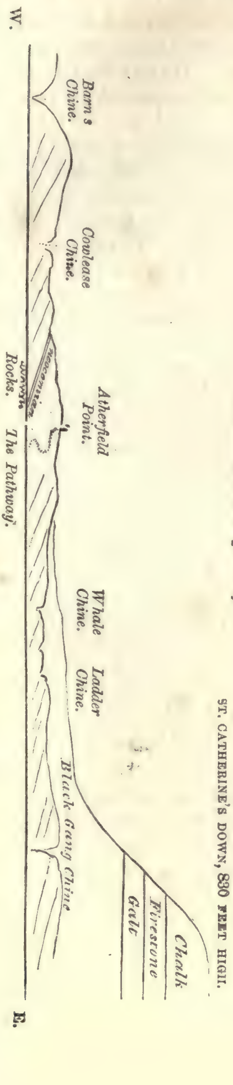


FIG. 281.—CONTINUATION OF THE COAST SECTION FROM GRANGE CHINE TO ST. CATHERINE'S DOWN.
(The distance about 5 miles.)

From Dr. Fitton's Memoir., Geol. Trans. Vol. iv. pl. xª

the trees retain their natural contour, and the bark, in many of them, is converted into a black carbonaceous substance, whilst the wood is fossilised. Hundreds of tons of this forest are seen stretching far out to sea, at low tides. Vegetable remains are frequently washed out of the cliffs; and bones from the wealden strata, which here form the bed of the British Channel, are cast on this and the adjacent shores.

ORGANIC REMAINS.—The fossil remains of the wealden consist of plants, fresh-water shells, fishes, turtles, pterodactyles, colossal reptiles, and birds. The shells are of fresh-water origin, consisting of the genera *Cyclas*, *Unio*, and *Paludina*, with an occasional admixture of marine and estuary species. The reptile remains are chiefly referable to the genera *Iguanodon*, *Hylæosaurus*, *Plesiosaurus*, *Megalosaurus*, *Cetiosaurus*. The plants are monocotyledonous, consisting chiefly of such as are allied to the fern, palm, Yucca, dracæna-draco, and other genera indigenous to the torrid zone, among which *Sphenopteris*, *Clathraria*, *Lonchopteris* are characteristic. (See fig. 123.)

SUSSEX MARBLE.—The weald clays contain beds of limestone composed of *Paludinæ*, a freshwater mollusc, common in rivers and lakes. This substance, when polished, is called Sussex marble, and was used for ornamental purposes by the Romans (fig. 282). During the middle ages it was employed for the decoration of sacred edifices. It forms a row of columns in Chichester cathedral; and in that of Canterbury, the throne is constructed of this rock. A highly interesting proof of its employment by the Romans was afforded, whilst digging the foundation of the present Council-house at Chichester, in 1723; the workmen discovered a slab of grey Sussex marble, which bore an inscription of which the following is a translation.

"The college, or company of artificers, and they who preside over sacred rites, or hold offices there, by the authority of King Cogidubnus, the legate of Tiberius Claudius Augustus, in Britain, dedicated this temple to Neptune and Minerva, for the welfare of the imperial family; Pudens, the son of Pudentinus, having given the site."

FOSSIL FISHES.—The strata of the wealden have yielded the scales, rays, teeth, and bones of fishes, allied to the *Lepidosteus*. These remains usually occur in a fragmentary

condition, occasioned by the transporting action to which they have been exposed. Species of the genera *Lepidotus*, *Pycnodus*, and *Hybodus* are found. The fishes of the wealden are specifically distinct from those of the chalk.

Fig. 282.—Sussex Marble, composed of Paludinæ.

Turtles.—The bones and other remains of turtles referable to one marine, and two freshwater genera, the *Emys* and *Trionyx*, have been exhumed from these deposits. The teeth and bones of crocodiles of two species have been discovered; the one allied to the gavial, with long, slender jaws; the other more nearly resembling the common crocodile. At Swanage, a highly interesting specimen of *Goniopholis* was obtained, which comprised the lower jaw, containing two teeth *in situ*, with several other scattered teeth, portions of the pelvis, ribs, and dermal plates.

Colossal Reptiles.—The most important discovery effected by Dr. Mantell in the region which he has raised to

geological celebrity, consists of those enormous reptiles which he has exhumed from the wealden.* This naturalist had long been in the habit of finding bones which differed from those of any known recent or extinct animal. Their characters were such as referred them to the reptilian type, yet their enormous size seemed to preclude such a supposition; for a reptile larger than an elephant was too monstrous for belief. At length, the discovery of a tooth (fig. 283), led him to conjecture the existence of a gigantic herbivorous saurian, holding the same rank among reptiles which was occupied by the elephant and mastodon among the mammalia. The teeth are of a prismatic form, with prominent ridges in front and serrated edges; the enamel is thick before and thin behind, so as to maintain constantly a sharp and cutting edge. The structure of the grinding surface proves that they are referable to a herbivorous species; the absence of a

FIG. 283.—A worn Tooth of the Iguanodon.

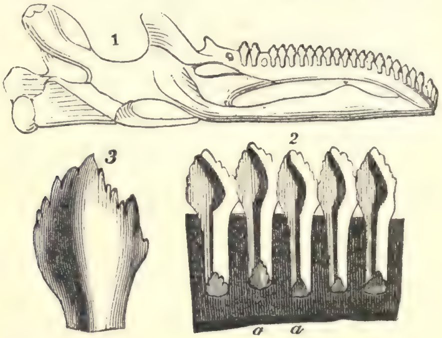


FIG. 284.—The Jaw and Teeth of the Iguana.

fang, and the appearance of the base, which is not broken off, but indented, show that the fang has been absorbed by

* For a complete and highly interesting account of these researches, the reader is referred to Dr. Mantell's Fossils of Tilgate Forest, and his Geology of the South-east of England.

the pressure of a new tooth, which grew up and supplanted the old one. Having recognised in the above the characters of the reptilian type, the dental structures of this class were next examined, till in the teeth and jaws of the *Iguana* he recognised a miniature resemblance of its colossal prototype. (Fig. 283.)

In fig. 1, of fig. 284, is the inner surface of the right side of the upper jaw; 2, a portion magnified four diameters; 3, a single tooth, largely magnified. At *a a* the intrusion of

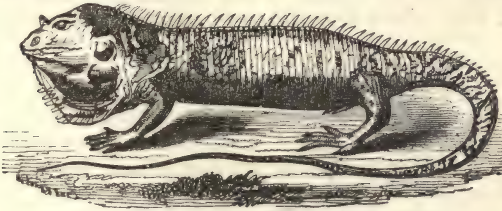


FIG. 285.—Iguana cornuta.

the new tooth into the base of the old is shown. The jaw forms a parapet on the outside of the teeth, but they have no protection inside, except the gum. Their prismatic form, serrated edge, the replacement of the old teeth by the new, the absorption of the fang, the mode of insertion in the jaw, their small size, when compared with that of the reptile to which they belong, sufficed to ally the recent with the fossil species, and induced its discoverer to name the extinct reptile *Iguanodon*. Many species of *Iguana* have large serrated processes along the back, while some have warty or horny protuberances on the head. The *Iguana cornuta* (fig. 285), in particular, which is a native of St. Domingo, has a

FIG. 286.—Horn of the Iguanodon.*

* The above specimen, which, with the rest of Dr. Mantell's collection, is in the British Museum, was considered unique, till Mr. Bass, jun., of Brighton, a short time since, obtained another.

small conical nasal horn; the fossil horn here depicted (fig. 286.) has been referred to the iguanodon, and is supposed to have occupied a similar position on the nasal bones.

Several bones belonging to the extremities of this saurian have been found in Sandown and Brook Bays, Isle of Wight; one femur measures 40 inches (fig. 199); another attains the colossal dimensions of 4 feet in length.

Professor Owen* dissents from the opinion that the iguanodon attained the length estimated from a comparison made between the bones of the iguana and that extinct reptile, and thinks that the relative proportions between the size of the bones in these genera is a premises not to be relied on, and suggests that the land reptiles of the wealden might have had limbs much longer in proportion to their length than the iguana of our epoch. The discovery of the Maidstone iguanodon, which comprises a larger portion of the skeleton than had previously been found, has served to confirm several important particulars relative to the general structure of the genus. This specimen was discovered in the lower greensand, which proves that the existence of this reptile was protracted till an early period of the chalk, as the remains of crocodiles and alligators are now borne by tropical rivers to the ocean; so these remains might have been floated by a river into the cretaceous sea.

THE HYLÆOSAURUS † was discovered in the strata of Tilgate forest. The peculiarity of this saurian consists in the large angular spinous bones which lie embedded with the skeleton. Many existing iguanas, as *Iguana cornuta*, have a fringe of cartilaginous spines, extending from the neck to the tail. In this extinct reptile the appendage is supposed to have been of bone, and to have been inserted in like manner along the back. Bones have been found in the Hastings sand which are referred to pterodactyles, and numerous large vertebræ from the wealden beds belong to a new genus, the *Cetiosaurus*, which is supposed to have had an alliance with the cetacean type of structure.

The Rev. P. B. Brodie discovered in the wealden of the Vale of Wardour, in Wiltshire, many genera of insects

* Report on British Fossil Reptiles.

† Ὑλαῖος (*hylæos*), a wood; σαῦρος (*sauros*), a reptile.

belonging to the orders *Diptera*, *Neuroptera*, *Hemiptera*, *Orthoptera*, and *Coleoptera*, and crustacea belonging to the genera *Archæoniscus* and *Cypris*, with shells of *Cyclas*, *Ostrea*, and *Paludina*, and several small fishes, which he has figured and described in his valuable Monograph on Fossil Insects. The gigantic reptiles which characterise the wealden of Kent and Sussex are absent from the Wiltshire beds, but the latter abound with many interesting forms of entomoid articulata, of which no trace has been found in the south-east of England.

DENUDATION OF THE WEALDEN.—In conclusion, we have to direct the student's attention to the evidences of denudation, so extensively presented throughout the wealden and the cretaceous groups. The removal of the chalk, and probably of the tertiary strata; the abrasion of the wealden beds; the proofs of displacement and fracture which they present; the anticlinal axis exhibited throughout a considerable part of their range; the fissures, which extend at right angles to the anticlinal line, and which form the present drainage of the district, constituting the beds of the rivers Arun, Adur, Ouse, and Cuckmere; these, with other facts of a like nature, prove that these strata have undergone upheaval and disturbance on the most extensive scale, at a comparatively recent period, probably during the tertiary epoch.

EXERCISES

ON THE WEALDEN FORMATION.

1. Explain the derivation of the term weald.
2. Name the authors and collections of fossils.
3. Mention its most important characteristics.
4. Describe the geographical distribution of the wealden.
5. Describe the general classification of its strata.
6. Mention the most important localities of its occurrence.

7. Describe its chief organic remains, and the inferences deducible from their occurrence.

8. Point out the chief physical features of these strata, and their evidence of disturbance.

9. Name any peculiar phenomena which are observable in deposits of this nature.

10. State any particulars of general or local interest connected with the history of this formation, and pursue the method of question and answer suggested in the previous chapter.

CHAPTER XIV.

THE OOLITIC GROUP.

Oolite formation of English; Calcaire Jurassique of French; Jurakalk, and Rogenstein of German Authors.

MUSEUMS:—Geological Society; British Museum; that of Dr. Buckland; the Bristol, York, Scarborough, Hull, Whitby, and Grantham Museums; with numerous private Collections.

AUTHORS:—Buckland, Lonsdale, Smith, Phillips, De la Beche, Murchison, Boblaye, De Caumont, Desnoyers, Goldfuss, Röemer, D'Orbigny, &c.

CHARACTERISTICS: — Marine, containing the usual Marine Exuviæ, with organic remains drifted from the Land, among which are the jaws of Mammalia, of the Marsupial Order.

DESCENDING a step in the scale of deposits, we reach the oolitic group, which underlies the wealden, or, where this is wanting, the chalk formation. Its name is derived from the Greek words, *ὠὸν*, an egg, and *λίθος*, a stone, because it is formed of small egg-like grains, like those composing the roe of a fish, the nucleus of which, on microscopic investigation, is found to be some minute substance, usually a fragment of a coral, a shell, or a grain of sand.

GEOGRAPHICAL DISTRIBUTION OF THE OOLITE.—This group commences at the Isle of Portland, and the adjacent coast of Dorset; and follows a winding course through the counties of Dorset, Somerset, Gloucester, Oxford, Northampton, Lincoln, and York, where it terminates at the sea, near Scarborough. On the Continent, it occurs in Normandy; and, diverging into various branches of hills, traverses France, forms the mass of the Jura and part of the Alps, and is farther developed in Germany and Poland, as well as in Portugal and Spain.

The oolitic group is highly valuable in an economical point

of view, from its consisting largely of limestones adapted for architectural purposes. It is subdivided into nine stages: the subjoined table shows these subdivisions and their equivalents, in England, Germany, and France:—

	Conybeare.	Roemer.	D'Orbigny.
Upper	Portland Stone and Sand.	Portland Kalk.	L'étage Portlandien.
	Kimmeridge Clay.	——	„ Kimmeridgien.
Middle.	Coral Rag.	Korallen Kalk.	„ Corallien.
	Oxford Clay.	Oxford Thon.	„ Oxfordien.
Lower	Cornbrash, Forest Marble, and Bradford Clay.	——	„ Callovien.
	Great Oolite and Stonesfield Slate.	——	„ Bathonien.
	Fuller's Earth and Inferior Oolite.	Walker Erde. Unter Oolith.	„ Bajocien.
Liasic	Upper Lias.	Possidonien schiefer.	„ Toarcien.
	Middle Lias.	Belemniten schichte.	„ Liasien.
	Lower Lias.	Lias Sandstein.	„ Sinèmurien.

The following analytical table shows the different stages, the lithological character, and principal localities of the oolitic group.*

Portland Stone and Sand.	Coarse oolitic shelly limestone; sometimes fine-grained or compact, thick-bedded, and with layers of chert, and with subordinate beds of sand.	Isle of Portland, Brill, and Aylesbury, Bucks; Thame, Oxon; Tisbury, near Swindon, Wilts
Kimmeridge Clay.	Dark blue and greyish laminated clay, with gypsum and bituminous shale.	Kimmeridge, Dorset; near Oxford; Stone and Hartwell, Bucks; near Swindon.
Upper Calcareous Grit, Coral Rag, Lower Calcareous Grit.	Coarse shelly limestones; more or less thick-bedded: coarse oolitic limestone, sandy limestones abounding in corals, calcareo-siliceous grits.	Headington, Oxon; Westbrook, Calne, and Steeple Ashton, Wilts; Malton and Scarboro', Yorkshire.

* Tennant's "British Fossils."

Oxford Clay, Kelloway Rock.	Dark blue clay, with Septaria; sometimes slaty and bituminous; with a subordinate band of ferruginous sandy limestone (Kel. Rock.)	Chippenham and Wooton Basset, Wilts; Oxford, Yorkshire, &c.
Cornbrash . . .	Coarse, rubbly limestone, thinly laminated with layers of clay.	Stanton, Malmsbury, Ashford, Wilts.
Forest Marble .	Thinly laminated shelly limestone, sand, and gritstone, with layers of clay.	Corsham, Box, &c., Wilts, Sapperton, Bradford; Cirencester.
Bradford Clay .	Layers of clay; sometimes alternating with bands of limestone.	Bradford, Burfield, Pickwick, Tetbury.
Great Oolite . .	Oolitic shelly limestone, more or less compact and sandy, sometimes thick-bedded.	Bath, Bradford, Minchinhampton Common (very fossiliferous.)
On the Yorkshire Coast the Great or Bath Oolite (b) (a hard blue limestone; fine-grained oolite; hard bluish clay;) is contained between two thick beds (a, c,) of gritty laminated sandstones and shales, containing an abundance of terrestrial plants.		(a) Clayton and Gristhorpe Bays. (b) Cloughton and White Nab. (c) Between Cloughton Wyke and Blue Wick.
Stonesfield Slate.	Oolitic, shelly and gritty limestone, slaty.	Stonesfield, Oxon; Sevenhampton Common, &c.
Fuller's Earth Clay.	. . . .	Bath, Box; near Stroud and Hampton Common.
Inferior Oolite .	Two layers of coarse shelly ragstone, with intervening bands of marl, and soft freestone. Fine grained sandstone and ironstone.	Dundry, Painswick; Brimscombe; the Cotteswold Hills; Blue Wick, Yorkshire.
Lias	Alum shale; rubbly and sandy shales, &c. Lower lias limestones and shales.	Whitby, Redcar, Yorkshire; Gloucestershire, Somerset, Lyme-Regis, &c.

The oolitic group is well developed in France, and is divided, by Alcide D'Orbigny, into ten stages. From the entire Jurassic series, this distinguished palæontologist has collected, for the illustration of his "Paléontologie Française," 3,785 species of fossil mollusca and radiata. The mode of their distribution is shown in the subjoined table, which exhibits the numerical value of the species that characterise each stage:—

Oolitic Group.	STAGES.	Number of Species of *Mollusca.*	Number of Species of *Radiata.*	Total Number in each Stage.	Total Number in the entire series.
Jurassic Series.	Portlandian	59	2	61	3,785
	Kimmeridgian	184	16	200	
	Corallian	403	235	638	
	Oxfordian	499	230	729	
	Callovian	253	25	278	
	Bathonian	407	125	532	
	Bajocian	508	94	602	
	Toarcian	273	14	287	
	Liasian	270	13	283	
	Sinèmurian	163	12	175	

Our limits restrict us to a few very general remarks on the fossils of this group. From the table of the distribution of Mollusca and Radiata in the French Jurassic series we observe that certain stages, as the Corallian and the Oxfordian, contain a much greater numerical proportion of corals and echinoderms than others; and the same fact has been observed in the English series. In the Portland beds, corals are rare, whilst one of the limestones of the middle oolite has received the name of coral rag, because it consists, for the most part, of zoophytic debris; many of the corals retaining the position in which they grew at the bed of the ancient sea.*

At Steeple Ashton are found *Astrea, Agaricia, Caryophyllia,* and *Explanaria,* and other genera, in great abundance and perfection. Similar coralline beds extend through Berkshire and Wilts, and occur likewise in Yorkshire. Many beautiful

* For lists of fossils of the oolitic, and other groups, we refer the student to the accurate catalogue of British fossils, by John Morris, Esq., a work of much research and great value. Very complete lists are contained in Mr. Tennant's book before cited.

corals are found in the great oolite near Bath, and an extended bed of coralline limestone rests upon the freestone of the inferior oolite of the Cotteswold Hills. Figures and descriptions of these corals, which belong, for the most part, to undescribed species from ancient coral reefs, will be given by Prof. Milne Edwards in his forthcoming monograph on the corals of the secondary rocks of England. Numerous crinoideans are met with in the different stages of this group. One genus, the *Apiocrinus rotundus* (fig. 160), is very characteristic of the Bradford clay. A general outline of the structure and distribution of the echinodermata has been given, in our chapter on Palæontology. The Mollusca are very abundant throughout the entire series, but certain forms characterise many of the stages. Thus *Ostrea deltoida* is found in the Kimmeridge clay of England and France, and *Gryphæa virgula* is so abundant in the upper oolites of France that the beds, from this circumstance, are called "Marnes à gryphées virgulé." The great oolite of Gloucestershire has been shown by John Lycett, Esq., to contain a suite of 320 species of Mollusca that are nearly all special to the Bathonian Stage, one half of which belong to the Gasteropoda, and a great many of the species are new.* Some of the most common and characteristic shells of the oolites are represented in fig. 287.†

The ferruginous beds of the inferior oolite at Dundry have yielded a beautiful series of well-preserved shells of Mollusca, and those of the Cotteswold Hills contain many well known, and a considerable number of new species.‡

Ammonites and Nautili are very abundant in the different stages of this group. The Oxford clay of Christian Malford has furnished some beautiful specimens of *A. Jason*, remarkable for having the lateral walls of the aperture prolonged into long spatulate processes (fig. 170).

Several species from the Kimmeridge clay, and from the inferior oolite of Dundry exhibit various modifications of the processes arising from the aperture of the shell.

* This beautiful series will form the subject of a monograph in the Pal. Soc. publications, by John Lycett and John Morris, Esqs.

† From Professor Phillip's Geology, Cab. Cyclopædia.

‡ Copious lists of the fossils from these beds are given in Sir R. Murchison's Geology of Cheltenham, Second Edition, by Messrs. Buckman and Strickland.

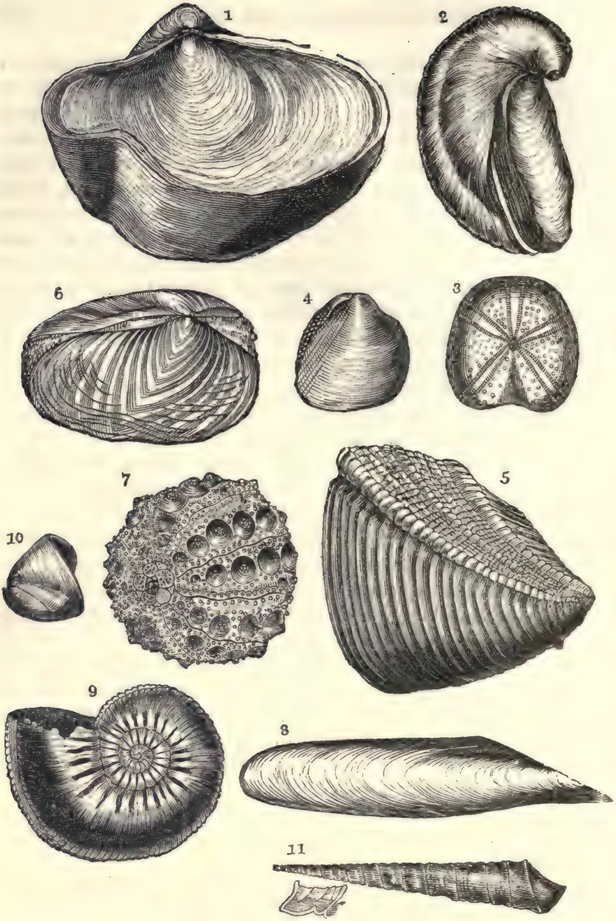


Fig. 287.

1. Gryphæa dilatata Sow. Kelloway rock and Oxford clay.
2. Gryphæa incurva Sow. Lower lias.
3. Nucleolites clunicularis. Cornbrash.
4. Cardium truncatum Sow. Lias marlstone.
5. Trigonia costata Sow. Inferior oolite.
6. Goniomya V scripta Agass. Inferior oolite.
7. Hemicidaris intermedia. Gt. oolite and coral rag.
8. Gervillia acuta Sow. Lower oolites.
9. Ammonites Calloviensis Sow. Kelloway rock.
10. Terebratula acuta Sow. Lias marlstone.
11. Nerinæa cingenda Voltz. Lower oolites.

The Stonesfield slate of Gloucestershire and Oxfordshire contains the remains of insects belonging to the families *Prioniidæ*, *Blapsidæ*, *Buprestidæ*, and others, which are figured and described by the Rev. Mr. Brodie. The remains of crustacea are rare in the inferior oolite, but the lithographic schists of Solenhofen, which belong to the Oxford stage have yielded many genera of this class.

The fishes formed a numerous section of the fauna of the oolitic period. Their history has disclosed the curious fact that all the *Lepidoïd* and *Sauroïd* fishes which lived in the seas before the deposition of the lias, had their vertebral column prolonged into the upper lobe of the tail, and are therefore called heterocercal, whilst all the *Lepidoïd* and *Sauroïd* fishes of the oolitic group, with one exception, the Coccolepis, found at Solenhofen, have the tail bilobed or homocercal, like the majority of the fishes of the present day. In our palæontological sketch we have cited the families most common in the different stages of the oolitic group.

The reptiles of the oolites are neither so numerous nor so well preserved as those of the lias. The most remarkable are the *Pterodactyles*, found in the Stonesfield slate of Oxfordshire and Gloucestershire, of which fig. 204 is a drawing of the skeleton, reduced from Goldfuss.

The MEGALOSAURUS was discovered by Dr. Buckland at Stonesfield; its teeth have been found in the equivalent bed in Gloucestershire; it was a gigantic carnivorous reptile allied to the crocodile and monitor, and, from the dimensions of its bones, must have attained a colossal size. The long bones of the extremities form hollow cylinders for the lodgment of marrow; the same anatomical fact has been observed in the femur of the iguanodon, and of all our terrestrial quadrupeds. The powerful teeth (fig. 200) had serrated edges, and combined in their construction the powers of the knife, the sabre, and the saw.

One of the most interesting discoveries in the palæontological history of the oolitic period is the presence of jaws and teeth in the Stonesfield slate, which have been referred to mammalia, and supposed to belong to extinct genera of the marsupialia, a group now found in the Australian continent. The fig. 216 represents the jaw of *Thylacotherium*, from Stonesfield: we have already alluded to the doubts which some entertain of its mammalian character.

Coal of the Oolite.—In the district north of the Humber, the lower beds of this formation assume a new character, and the forest marble and great oolite are replaced by beds of sandstone, shale, and carbonaceous matter. The coal, though greatly inferior both in quality and extent to that of the carboniferous group, never exceeding sixteen inches in thickness, is of considerable local value. Fossil plants are found in the sandstones which accompany the coal: and in Gristhorpe Bay a seam of shale is traceable for a considerable distance, containing leaves of ferns, *Equisetæ*, *Cycadeæ*, &c., specimens of which are in the British Museum. A similar deposit of coal was discovered at Brora, in Scotland, and was worked, from patriotic motives, by the late Duke of Sutherland; but, from the great loss incurred thereby, the works are now given up.

EXERCISES

ON THE OOLITIC GROUP.

1. State the derivation of the term oolite.
2. Describe the general geographical distribution of these beds.
3. Name their localities in other countries.
4. Mention the chief authors and collections.
5. Describe the principal characteristics of the group.
6. Point out the sub-divisions of the beds.
7. Mention their respective mineral characters.
8. State their principal fossil remains.
9. Describe any fossil objects of extraordinary nature and interest which have been discovered in this group.
10. Trace on a map and commit to memory the general direction of the strata, and name the counties in which they occur.
11. Mention their economical and commercial relations.
12. State any facts of a generally interesting and instructive nature connected with this group, and consult the foregoing epitome for questions and answers on the principal features of its history.

CHAPTER XV.

THE LIAS.

Lias of English ; Calcaire a Gryphites of French ; and Gryphitenkalk and Jura-kalk of German Authors.

MUSEUMS :—British Museum, those of Scarborough, Whitby, of Viscount Enniskillen, Sir P. Egerton, Professor Sedgwick, and those of Dorsetshire, Yorkshire, and the Midland Counties.

AUTHORS :—Buckland, Conybeare, Phillips, De la Beche, Murchison, Roemer, Koch, and Dunker.

CHARACTERISTICS :—A Marine deposit, chiefly remarkable for the remains of enormous Reptiles, principally of the Genera Ichthyosaurus and Plesiosaurus.

THE English provincial name lias has been very generally adopted for a formation of argillaceous limestone, marl, and clay, which forms the base of the oolite, and is classed by many geologists as part of that group. They pass, indeed, into each other in some places, as near Bath, a sandy marl called the marlstone of the lias being interposed, and partaking of the mineral characters of the upper lias and inferior oolite. These last mentioned divisions have also some fossils in common, such as *Avicula inæquivalvis.*

Nevertheless the lias may be traced throughout a great part of Europe as a separate and independent group, oı considerable thickness, varying from 500 to 1000 feet, containing many peculiar fossils, and having a very uniform lithological aspect. Although usually conformable to the oolite, it is sometimes as in the Jura, unconformable. Thus, in the environs of Lons-le-Saulnier, for instance, the strata of lias are inclined at an angle of about 45°, while the incumbent oolitic marls are horizontal.*

The peculiar aspect which is most characteristic of the

* Sir C. Lyell, Elements of Geology, First Edition, page 386.

lias in England, France, and Germany, is an alternation of thin beds of limestone, with a light brown weathered surface, separated by dark-coloured narrow argillaceous partings, so that the quarries of this rock, at a distance, assume a striped and riband-like appearance.*

Geographical Distribution.—The lias, like the oolite, forms a belt which extends across our island, from its south-western to its north-eastern shores, from Lyme-Regis, in Dorsetshire, to the north of Whitby, where it is lost beneath the moorlands of the Yorkshire coast. It accompanies the oolite with considerable regularity, from Lyme-Regis through Dorsetshire and Somersetshire to Gloucestershire, in which county, about six miles south of Gloucester, its western portion diverges still farther to the west, and pursues a tortuous and intricate course, among the counties of Somerset, Gloucester, Monmouth, and Glamorgan, attended with outlying portions and detached masses. Its eastern portion continues a regular track through parts of Gloucestershire, Worcestershire, Warwickshire, Leicestershire, Lincolnshire, and Nottinghamshire, into Yorkshire.

On the continent, this formation is largely developed, in the north and south-east of France, in Switzerland, and Germany. In some countries, as in America, it is wanting over extensive areas.

No part of the world has yielded organic remains of such an interesting character as those which have been brought to light in this country, an unrivalled collection of which constitutes an important feature in the assemblage of organic remains contained in the mineral-galleries of the British Museum.

In Gloucestershire the lias admits of a fourfold division, into—

1. Upper lias shales ;	2. Lias marlstone ;
3. Lower lias shales ;	4. Lias limestone.

The upper shales are seldom well exposed in the escarpments of the Cotteswolds, but are seen in situ in the liasic outliers of Dumbleton and Alderton, reposing on beds of marlstone, which in these localities are extremely rich

* Geology of England and Wales, page 261.

in fossil shells. In Yorkshire a similar division of the lias has been observed.*

FAUNA OF THE LIAS.—Corals are rarely found in this stage, but in Warwickshire some beautiful masses of *Astrea* have been discovered. The bed of the liasic sea was strewed with numerous plant-like Crinoideans belonging to the genus *Pentacrinus;* many fine specimens of *P. briareus*, have been obtained from Lyme-Regis. A few slender armed *Ophiura* have been found in the same rich locality. Larger species are preserved in the shales of Gloucestershire, and in the marlstone of Yorkshire. The genus *Cidaris* is likewise found in the Vale of Gloucester. The Conchiferous Mollusca were very abundant in many localities; numerous individuals of the genera *Gryphœa, Cardinia, Lima, Avicula,* and *Hippopodium*, are found in the lower lias shales. *Crenatula,*

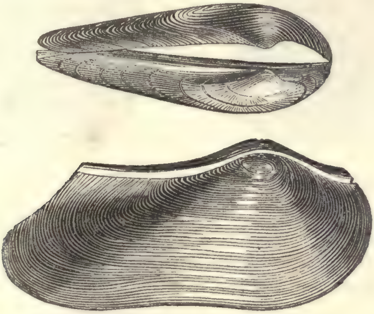


FIG. 288.—Arca Buckmanni.

Corbula, Pholadomya, and *Nucula,* occur in a higher zone, and a species of *Arca* (fig. 288) is found in the upper beds of the lower lias shales. The plate (fig. 289) exhibits some of the most common and characteristic genera of liasic shells.

The Marlstone contains many conchifers that are special to it, as *Gryphœa gigantea, Pinna Hartmanni, Avicula cygnipes,*

* For full particulars relating to the lithological character of these beds, the student is referred to Sir R. Murchison's Geology of Cheltenham, Second Edition; Professor John Phillips' Geology of Yorkshire; and the Rev. P. B. Brodie's Fossil Insects.

Cardium truncatum, (fig. 287) and *Pecten equivalvis.* The Brachiopoda were represented by many species of *Terebratula*, and the ancient genus *Spirifera*, which had swarmed

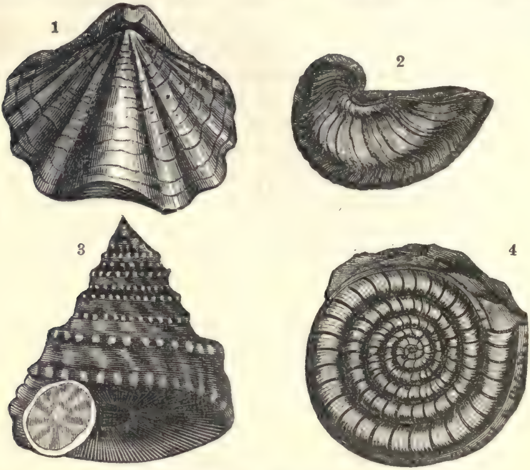


FIG. 289.—1. Spirifer Walcottii. 2. Gryphæa incurva. 3. Pleurotomaria Anglica. 4. Ammonites Conybeari.

in the seas of the Silurian, Devonian, and Carboniferous periods, appears in the lias for the last time.

Sp. Walcottii is characteristic of the lower lias shales, and

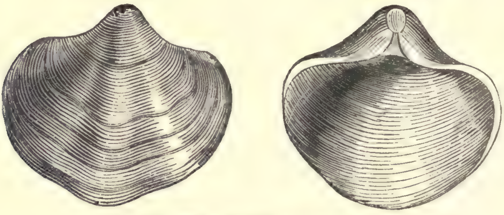


FIG. 290.—Spirifera punctata.

Sp. punctatus (fig. 290) was found in a higher bed; the genus *Leptæna* is represented in the lias of Ilminster.

Gasteropoda are rare in the lias; the most remarkable is the extinct genus *Pleurotomaria*, of which several species are found. Magnificent specimens of a large species, (*P. Anglica?*) were found near Bredon. Another species known as *Rotella* is special to the marlstone.

The Cephalopoda are very abundant in the liasic beds. Seventeen species of Belemnites occur in the lias of France, and nearly as many are found in those of England. The internal shells of a genus of the family Loligidæ, have been found in the lower lias of Cheltenham;* in the same stratum three species of Nautilus, *N. striatus*, *N. semistriatus*, and *N. intermedius*, are found, and in the Marlstone one species, *N. inornatus*, is special to it. D'Orbigny has figured and described one hundred and forty-two species of Ammonites, from the lower, middle, and upper lias of France, and a great number of the same species are found in the lias of Gloucestershire. The different groups of Ammonites contain species that characterise the several zones of the liasic beds. Thus, in the inferior zone of the lower lias shales, we find *A. bisulcatus*, *A. obtusus*, *A. subarmatus*, *A. liasicus*, *A. tortilis*, *A. Conybeari*, *A. Birchii*. In the superior zone of the lower lias shales, *A. planicosta*, *A. Boblayei*, *A. Valdani*, *A. Henleyi*. In the Marlstone of Dumbleton, *A. spinatus*, *A. Engelhardti*, *A. margaritatus*, and *A. heterophyllus*. In the upper lias shales, *A. bifrons*, *A. serpentinus*, *A. annulatus*, and *A. ovatus*.

We have already stated that with the lias, an important modification in the structure of fishes was introduced; many genera of the Ganoid order with equal lobed tails are found in the lias of Lyme and Whitby, as *Tetragonolepis*, *Dapedium*, *Amblyurus*, *Semionotus*, and *Lepidotus*, but for further details relating to this class we must refer to the great work by Agassiz on fossil fishes, to our chapter on palæontology, and to the lists of British fossils already cited for the genera and the localities from whence they are obtained.

A thin seam of insect limestone lying near the base of the lower lias beds, and exposed at Wainlode and Westbury cliffs, on the banks of the Severn, has yielded Insects belonging to several families of Coleoptera, Orthoptera, and others,

* We have recently found internal shells of Loligidæ in the upper lias of Dumbleton.

and that of Worcestershire, the beautiful *Æshna liassina* (fig. 178).

Another thin band of fissile limestone, which traverses the upper lias has afforded likewise the remains of Neuropterous and other insects, so that the two zones of insect limestone, which bound as it were the great liasic group of England, contain the remains of beautifully preserved air-breathing articulata, thereby attesting the proximity of dry land to the ocean which was tenanted by the colossal saurians.

Crustacea belonging to the genus *Coleia* and minute shells supposed to be *Cyproida* are found in the lower lias of the Vale of Gloucester, and from the same stratum two species of *Astacus* have been obtained.

Reptiles of the Lias.—The most marvellous of all the remains intombed in the lias, are the marine Saurian reptiles, belonging to the family *Ichthyosauridæ;* the genera with which we are best acquainted, are the *Ichthyosaurus* and the *Plesiosaurus.*

The Ichthyosaurus (from ιχθυς, fish, and σαυρα, a lizard) like its congener, the *Plesiosaurus*, is remarkable for uniting such combinations of structure as are now distributed through various classes of animals, but which no longer exist in any one. Thus it possessed the snout of a porpoise, the teeth of a crocodile, the head of a lizard, the sternal arch of the *Ornithorhynchus*, the paddles of a whale, and the vertebræ of a fish. Its general outline is considered to have most nearly resembled that of the porpoise. The teeth are numerous, sharp, conical, and striated, resembling those of a crocodile; they are also supplied by replacing teeth, in the same manner as in that saurian. The eye was of enormous magnitude, and the sclerotic or outer coat was encircled by a series of thin bony plates, as in chelonia and in some birds, especially the golden eagle, an arrangement which gives an immense extent and power of vision. The sternum and collar bones resemble in structure those of the *Ornithorhynchus*, the construction in both creatures being intended to adapt them for an aquatic life. The two fore-paddles were large, and composed of about one hundred bones, while the hinder pair are smaller, consisting only of thirty or forty. The vertebræ are biconcave, like those of fishes. Of this genus ten species are known in the lias.

THE PLESIOSAURUS, (from πλεσιον, akin to, and σαυρα a lizard.)—This reptile, as its name imports, was more nearly allied to the lizard than the fish, especially as regards the character of its vertebræ. Like the *Ichthyosaurus*, it united in its structure various types of organisation; it had the head of a lizard, the teeth of a crocodile, a neck of enormous length, resembling the body of a serpent, a back and tail having the proportions of an ordinary quadruped, the ribs of a chameleon, and the paddles of a whale. It is supposed to have so far differed in its habits from the *Ichthyosaurus*, that while that creature sought the depths of the ocean, the *Plesiosaurus* is considered to have floated upon or near the surface of shallow waters; arching back its long neck like a swan, and occasionally darting it at the fish which swam within its reach. Ten species of this genus are found in the liasic beds, but several others are special to the higher stages of the oolitic group.

One of the most remarkable species is the *Plesiosaurus rugosus*, which was recently presented to the British Museum by the Duke of Rutland, and described by Professor Owen: it is characterised by certain rugose markings on the vertebræ and other parts of the skeleton. Figure (fig. 291) is a faithful representation of the specimen; *a*, is two vertebræ, with rugose edges. The most perfect specimen of plesiosaurus yet brought to light is one recently discovered at Whitby, which has been purchased at the price of 230*l*. for the Fitzwilliam Museum, at Cambridge. This saurian has been described by Professor Owen under the name *P. grandipinnis*, from the large size of its paddles. (See fig. 203.)

From the state of perfection in which these and other specimens have been discovered, many of the skeletons containing between their ribs the scales and other remains of fishes, it is inferred that they must have been suddenly destroyed, and entombed in the sediment in which they are now enveloped.

ORIGIN OF THE OOLITE AND LIAS.—It is supposed that the ocean which deposited these groups was liable to sudden changes; the varied nature of the beds probably justifies this inference, as argillaceous, arenaceous, and calcareous strata are found to succeed each other, the clay usually forming

the substratum of each series. These alternations are

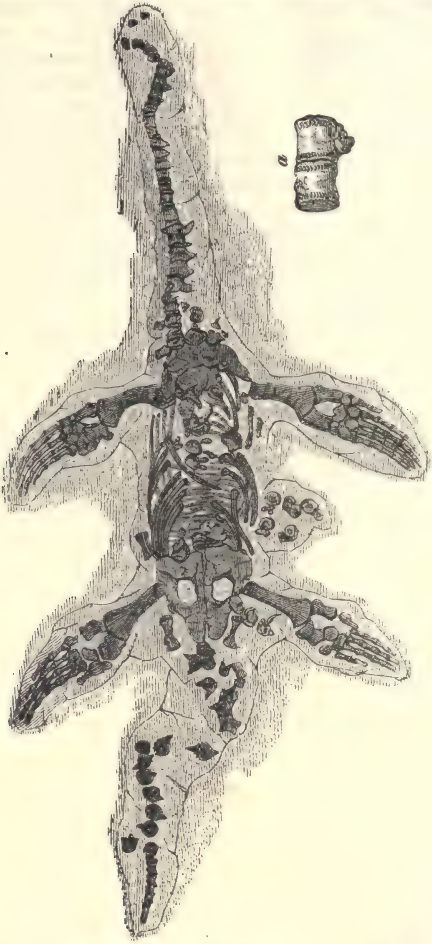


FIG. 291.--Plesiosaurus rugosus. Owen.

accounted for on the supposition that a sea, which, during a

certain period, threw down deposits of clay, or mud, ceased to do so after a time, either from a change in its currents, or from the destruction or removal of the land which had supplied the substance previously precipitated; under altered conditions the same waters might deposit beds of sand, or afford conditions favourable for the growth of zoophytes, and thus produce the argillaceous, arenaceous, and calcareous deposits observable in different portions of this group.

EXERCISES

ON THE LIAS FORMATION.

1. Explain the meaning of the term lias.
2. Mention the chief authors and collections.
3. Name the distinctive features of the formation.
4. Mention the principal discoverers and collectors.
5. Describe the characteristic shells and fossils.
6. State the division of the beds.
7. Trace the geographical distribution of these deposits in this country and on the Continent.
8. Name the counties in which they occur in England.
9. Point out any particular phenomena indicated by their organic remains.
10. Name the chief localities in which fossils have been discovered.
11. Mention the most recent discoveries effected in these deposits.
12. State any facts of general and instructive interest, and pursue the prescribed method of question and answer.

CHAPTER XVI.

TRIAS, OR NEW RED SANDSTONE GROUP.

New Red Sandstone; Triasic, or Saliferous, or Poikilitic* System of English Authors.

1.—Red, or Variegated Marls of English; Marnes Irisées and Calcaire Conchylien of French; and Keuper and Muschelkalk of German Authors.

2.—New Red and Variegated Sandstone of English; Grès Bigarre of French; and Bunter Sandstein of German Authors.†

3.—Magnesian Limestone of English; Zechstein of Germans.

4.—Lower New Red Sandstone of English; Grès des Vosges of French; Rothtodt-liegendes of Germans.†

The entire formation is also styled "Trias" in Germany, because it there consists of three principal portions; first, the Variegated Marls; secondly, the Muschelkalk; and, thirdly, the Variegated Sandstone. The Muschelkalk, though extensively developed in Germany, is wanting throughout the whole of France, with the exception of the environs of the Vosges Mountains, while in England it is absent altogether.

Museums:—Geological Society, that of Warwick, and other local Collections

Authors:—Murchison, Lyell, Sedgwick, Jaeger, Voltz, Elie de Beaumont, &c.

Characteristics:—A Marine formation, comparatively poor in Fossils; remarkable for the traces of Footsteps of Animals, and for its Springs of Brine and Stores of Rock-Salt, hence called the Saliferous, and also, from the diversified Tints of the Strata, the Poikilitic or Variegated Group.

Beneath the lias occurs, in the midland and western counties of England, a vast series of red marls and sandstones, which

* From ποικίλος, varied or mottled, from the appearance of these deposits.

† Of the German names above cited, the derivation of *Keuper*, which is supposed to be a miner's term, is wholly unknown. *Muschelkalk* is employed to designate a limestone containing *Mytili*. *Bunter Sandstein*, or variegated sandstone, is sufficiently clear. *Zechstein*, again, is obscure, but its derivation is referred by Adelung to the signification of *zech*, which means a company or association, who were accustomed to hire a pit or a quarry, for the purpose of working it, in this instance probably for copper. *Rothtodt-liegendes*, literally, *red-dead-lier*, is used to indicate that the copper found in the upper beds has died out, and is not met with in these underlying deposits.

are succeeded by beds of limestone. The marl and sandstone beds are of varied tints, though a dull red derived from peroxyde of iron chiefly predominates. The name of *new red* is given to this group to distinguish it from the *old red* sandstone, which is often identical with it in mineral characters, but usually lies beneath the coal, though in some local instances, in particular the great coal field of Dudley, the old red sandstone, which is sometimes ten thousand feet thick, is wanting, and the beds of coal repose on the underlying Silurian system.

The following table exhibits the distribution of these strata in the British localities in which they occur:—

I. Upper new red sandstone, or saliferous system.
  Saliferous marls and sandstones.
  Sandstone and quartzose conglomerate.

II. Lower new red sandstone.
  Magnesian limestone.
  Lower new red sandstone.

GEOGRAPHICAL DISTRIBUTION.—This system, like the last two groups, traverses our island from south-west to north-east, and accompanies the lias from Devonshire and Somersetshire, through the midland districts of Gloucestershire, Warwickshire, Lancashire, and Yorkshire, to Cumberland. It forms a region highly favoured by Nature, though poor in fossil remains, containing rich stores of gypsum, soda, and salt, and, from immediately overlying the coal, presents at once such a stimulus and supply to industry, that nineteen of our principal cities and chief seats of commerce, from Exeter to Carlisle, are located on strata appertaining to this group. Deposits of this character are largely developed in France, in Germany, Italy, and European Russia, as well as North America.

ROCK-SALT AND BRINE SPRINGS.—We have mentioned, among the characteristics of this formation, its brine-springs and stores of rock salt, which entitle this group to the name of saliferous. The beds of new red sandstone which prevail in Cheshire, where the chief salt-works are established at Northwich, and in Worcestershire, where the most important springs exist at Droitwich, yield an inexhaustible supply.

There is historical evidence of their having been wrought by the Britons, and for 2000 years they have never failed. In the year 1725, it having been ascertained that the strata at Northwich were perforated to a greater depth than those at Droitwich, the gypsum-beds of that place were broken through, when springs of much stronger brine poured into the pits, and by yielding a more valuable supply, greatly enhanced the productiveness of the works. The bed of gypsum lies about forty or fifty feet below the surface; it is a hundred and fifty feet thick, and on being perforated the stream of brine is reached, which is about two feet in depth, and rests on a bed of rock-salt. The brine rises through the perforation, and is conveyed into iron boilers, for the purpose of evaporation. Brine-springs are produced by streams of water which have flowed over masses of rock-salt; but the origin of that mineral substance is by no means so easy of explanation. It constitutes a problem which the present state of our knowledge does not enable us to solve. Three theories have been proposed to account for its origin: the first ascribing it to the evaporation of sea-water, and considering it to have been deposited in the bed of a sea; the second referring it to similar depositions from a salt-water lake; and the third attributing it to volcanic agency. The first two propositions are liable to the objection of the great depth of water requisite for producing masses of rock-salt forty yards in thickness; or a mountain of salt six hundred feet in height, and twelve hundred in breadth at its base, such as is known to exist at Cardona, in Spain. The most conclusive proof in favour of the volcanic theory consists in the perfect freedom of the rock-salt from extraneous matter; whereas if it had been deposited by salt-water, it would have presented some imbedded substances indicative of its sedimentary origin. The volcanic theory is strengthened by the facts that chloride of sodium is of common occurrence among the ejections of volcanoes, and that salt-springs rise to the surface from granitic rocks; whence it is inferred that the sources which supply the salt may lie as deep as those substances which yield the materials for modern lavas, and which have furnished the elements for the ancient trap-rocks and basalts in the early history of the earth.

ORGANIC REMAINS OF THE UPPER NEW RED SANDSTONE.—We have already observed that the dull red colour prevalent in strata of this formation is derived from an oxide of iron, and it has been noticed as a striking fact, that all deposits in which this iron prevails are deficient in fossils; thus the new red sandstone exhibits a remarkable paucity of organic remains as contrasted with the oolite and lias. In Germany, where this group is largely developed, the calcareous strata, especially the *muschelkalk*, are comparatively rich in organic remains. Of plants, several *Cycadeæ*, and various genera of ferns, with *Voltzia*, *Albertia*, and *Equisetum*, have been collected by Count Münster; of Mollusca, the *Posidonia minuta* and *Avicula socialis*, with Ammonites of the form called *Ceratite*, have been discovered in these strata. It is, however, remarked that the red sandstone is relatively deficient in fossils; and that the organic remains chiefly occur in the argillaceous and calcareous beds.

FOSSIL FOOTMARKS.—The impression of footmarks of a peculiar character, occurring both in this country and in Germany, have formed a most interesting subject of inquiry. Imprints had been observed in strata of this formation, in some quarries at the village of Hesseberg, near Hildburghausen, in Saxony, and were referred to a large unknown quadruped, which, from the resemblance of the markings to those of a human hand, were provisionally named, by Professor Kaup, *Chirotherium*, or hand-beast, which was supposed by him to have been allied to the *Marsupialia*, since in the kangaroo the first toe of the fore-foot is set obliquely to the others, like a thumb (fig. 292).

The larger impressions, which seem to be those of the hind foot, are usually eight inches in length and five in breadth. At about an inch and a half before this impression a smaller print of a fore-foot, four inches long and three inches wide, occurs. The footmarks follow each other in pairs, each pair in the same line, at an interval of fourteen inches between each pair. Both the large and the small steps show the great toe alternately on the right and left side; each step makes the print of five toes, the first or great toe being bent inwards like a thumb. Though the fore and hind feet differ so considerably in size, they are nearly similar in form.

Some time since, similar impressions were observed in strata of the same date, in five superimposed beds of clay at the Storton Quarries, on the Cheshire shore of the Mersey, and which, like the imprints previously discovered

FIG. 292.—Line of footmarks on a slab of sandstone. Hildburghausen, Saxony.

in Germany, were referred to the presumed marsupial animal *Chirotherium*. These footmarks exercised for some time the ingenuity of naturalists; and, among other conclusions, it was inferred that impressions of such depth and distinctness could only have been made by animals walking on dry land, as their weight would have been insufficient to cause them to sink so deeply in yielding clay under water. It was farther supposed that each layer of clay which bore these imprints had been afterwards submerged, so that a new stratum was successively formed above the former. Professor Owen having directed his attention to these footmarks, and to the remains of reptiles, consisting of bones and teeth, which had been observed in beds of this age in Germany and England, arrived at the conclusion that the impressions were made by an animal of a different class. The fossil teeth exhibited externally the reptile type, but internally they presented a most complicated texture, differing from that of all other reptiles hitherto discovered. A section of one of these teeth, under the microscope, presents a series of irregular folds, resembling the labyrinthic windings of the human brain: from this circumstance the name *Labyrinthodon* was proposed for the genus.

An examination of the various bones, procured from the same formation, enabled him to describe five species of this new genus, which had the posterior extremities much larger than the anterior. Hence the idea was first suggested that the tracks in question were those of the *Labyrinthodon*. It was farther observed, that the footprints of *Chirotherium* were more like those of toads than of any other living

animal; and that the size of the three species corresponded with that of the three different kinds of footsteps which had already been supposed to belong to three distinct individuals. Finally, the structure of the nasal cavity showed the *Labyrinthodon* to be an air-breathing reptile, since the posterior outlets were at the back part of the mouth, instead of being directly under the anterior or external nostrils. It must, therefore, have respired air, like the saurians, and, in all probability, may have imprinted on the shore those footsteps which were supposed to have been produced by an animal walking on dry land.

MAGNESIAN LIMESTONE OR ZECHSTEIN.—The inferior members of the new red sandstone formation consist, in the south-west of England, of a conglomerate, formed of pebbles cemented together by a base of dolomite or magnesian limestone, whence it is termed dolomitic conglomerate. The imbedded fragments chiefly consist of the *débris* of the rocks on which they repose, such as fragments of mountain-limestone, coal, shale, and other underlying deposits. In the north of England these conglomerates and breccias are represented by the magnesian limestone. The magnesian limestone is now separated from the Trias into a distinct system, under the name of PERMIAN, from Perm, a Russian government; where strata of this group are extensively developed, occupying an area twice the size of France, and containing a special Fauna. Mr. King classifies * the Permian group of the north of England into six stages, which he is of opinion represent the Thuringian strata:—

NORTH OF ENGLAND.	THURINGIA.
1. Crystalline limestone.	1. Stinkstein.
2. Brecciated limestone.	2. Rauchwacke.
3. Fossiliferous limestone.	3. Dolomit, Up. Zechstein.
4. Compact limestone.	4. Zechstein, Low. „
5. Marl slate.	5. Mergel-schiefer.
6. Inferior sandstones.	6. Rothliegendes.

The magnesian-limestone has lately been brought into repute for architectural purposes, buildings constructed of it having been ascertained to be extremely durable. The

* Pal. Soc. Memoir.

stone is found to combine the varied qualities so much desired by the architect, but so seldom found in the same material; uniting the softness and facility of working of the oolite above, with the hardness and compact texture of the more crystalline rocks below; while the magnesia which it contains is unfavourable to vegetable growth. Qualities thus valuable induced the members of the commission for selecting stone for the new houses of Parliament, to give the preference to this material over all others which they had the opportunity of inspecting. It was remarked that in this stone, the carbonates of lime and of magnesia exist in nearly equal proportions. In many instances, this substance presents singular examples of spheroidal structure, induced, it is conceived, after the deposition of the stratified mass.

Organic Remains. — We have already observed, that where certain strata resemble in mineral structure the beds above, the fossils which they contain often present an affinity with the rocks beneath; and, in the present instance, those of the Permian partake rather of the types of the carboniferous group below, than of the new red sandstone above, the shells being of the genera *Spirifera* and *Producta;* while the fish are remarkable for that peculiarity of structure in the tail called heterocercal, in which the vertebral column *extends into the upper lobe*, whilst, in homocercal fishes, the tail is either single or bilobed, and the spine *does not extend into either.* (Figs. 293, 294).

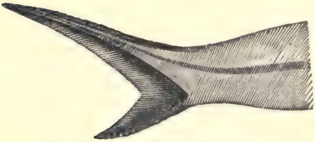


Fig. 293.—Heterocercal; Shark.

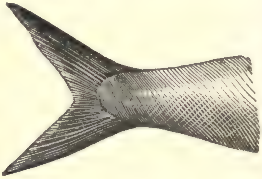


Fig. 294.—Homocercal; Herring.

On this peculiarity of the tail in the sturgeon and shark, Dr. Buckland remarks that the prolongation of the vertebral column is calculated to sustain the body in an inclined position, with the head and mouth nearest to the bottom.

Of the two fish above named, he observes, that the former perform the office of scavengers, to clear the water of impurities, as they have no teeth, but feed at the bottom, on putrid animal and vegetable substances, by means of a soft, leather-like mouth, capable of protrusion and retraction; hence they have occasion to keep their bodies in the same inclined position as the extinct fossil fishes of this formation, the *Palæoniscus*, whose small and numerous teeth show that they also fed on like substances in similar situations.

EXERCISES

ON THE TRIASIC AND PERMIAN GROUPS.

1. Describe the authors and collections.
2. Point out the general features of these groups.
3. Mention their principal geographical distribution.
4. Trace their occurrence on the map.
5. Name the counties where they are developed.
6. State the division of the strata.
7. Mention their mineral composition.
8. Point out those which contain organic remains.
9. State the presumed cause of the paucity of fossils in some rocks of this group.
10. Mention the mineral contents of the strata.
11. State the localities of their occurrence.
12. Mention any general facts of interest or importance connected with these deposits, and the questions and answers illustrative of their history.

CHAPTER XVII.

THE CARBONIFEROUS GROUP.

Coal-measures of English; Terrain Houiller of French; Kohlen-Gebilde of German Authors.

MUSEUMS:—British Museum, Geological Society, those of Newcastle, Dudley, Leeds, Halifax, Edinburgh, Glasgow, Dublin, and the Cabinets of many Private Collectors.

AUTHORS:—Buckland, Lindley and Hutton, Artis, Witham, Phillips, Martin, Farey, Brongniart, Sternberg, Presl, Cotta, Corda, Knorr, Schlotheim.

CHARACTERISTICS:—A vast group, composed of alternations of Marine and Freshwater Strata, beds of Ironstone and Coal, with Shales and Grits, remarkable for the abundance and variety of their Fossil Plants.

WE have so often had occasion to allude to the coal formation, that a mere outline of its principal and characteristic features will suffice for the present description, and for more ample details we must refer to the various works of the authors above quoted, which treat at length of this highly interesting and important group.

The coal-fields of the British islands are extremely numerous, and the distribution of the beds varies according to local circumstances. The following will, however, be found to afford a general outline of their disposition and arrangement.

Coal-measures.

Strata of shale, sandstone, and grit, with occasional seams of coal and layers of ironstone.

Millstone grit.

A coarse quartzose sandstone, passing into a conglomerate, sometimes used for millstones.

Carboniferous limestone, or mountain limestone; a calcareous rock, containing marine shells and corals.

The following table, by Professor Phillips, shows the com-

parative structure of the carboniferous group in the south of England and South Wales, Derbyshire, and Yorkshire.

South of England.	Derbyshire.	Yorkshire.
Coal Formation, Millstone Grit (*not very thick*), Mountain Limestone, Old Red Sandstone.	Coal Formation, Millstone Grit, Limestone Shale, Mountain Limestone, Old Red Sandstone (*not much developed*).	Coal Formation, Millstone Grit, Yoredale Rocks, Scar Limestone, alternations of Red Sandstones, Clays, and Limestone; Red Sandstone, and Conglomerate.

In the upper part of the coal measures in Shropshire, a fresh-water deposit extends for about 30 miles, and in Coalbrook Dale a fresh-water deposit containing the shells of *Unio*, a river mussel, is found to alternate with a marine bed containing *Spirifera* and *Nautilus*. Analogous conditions have been found in Yorkshire and Scotland.

It will be seen that the coal forms but a relatively small part of the formation to which it gives its name, since it occurs in comparatively thin seams, amid masses of rock of far greater size and extent.

In addition to the remarks already suggested on the importance of coal, we may observe that its value, in this country, is enhanced to an incalculable extent by its association with beds of iron-ore occurring in the contiguous shales; while these, again, could not be fused without the aid of limestone, which acts as a flux, and promotes the speedy reduction of the ore. In other countries, where the beds of coal are not accompanied by like deposits, as in Silesia, where they are associated with rocks of older date, and in various parts of France, where the coal is similarly situated, its value is restricted to its mere employment as fuel; these countries are thus deprived of the commercial advantages which we enjoy from its favourable distribution in the British Isles.

THE COAL-FIELDS OF ENGLAND AND WALES.—These are arranged by Conybeare and Phillips, into

I.—The coal-fields north of the Trent, comprising those of

1. Northumberland and Durham.
2. Yorkshire, Nottinghamshire, and Derbyshire.
3. North Staffordshire sometimes called the Pottery coal-field.

4. Manchester.
5. Whitehaven.

II.—The Central coal-fields, including those of

1. Leicestershire.
2. North Staffordshire.

III.—The Western, divided into

1. The North-western, containing those of North Wales.
2. The Western, comprising those of the Plain of Shrewsbury; of Coalbrook Dale and the Clee Hills.
3. The South-western, comprising the coal-fields of South Wales, of the Forest of Dean, and those of Gloucestershire and Somersetshire.*

Coal also exists in France, the Netherlands, the banks of the Rhine, in Saxony and Bohemia, in Sweden and Russia, in Persia, China, and Hindostan, in North and South America, and Australia.

Igneous Rocks.—These are frequent in the carboniferous group of this country, occurring as overlying stratiform masses alternating with sedimentary deposits; but more frequently as dikes, which have penetrated through the strata. In England, the principal intrusions of these rocks consist of greenstone and basalt, locally termed whinstone in the North of England; the toadstone of Derbyshire, so called from its mottled appearance; and the basaltic masses of the South Staffordshire or Dudley coal-field belong to these rocks. The dikes exhibit the effects usually observed at the point of contact of rocks of this character with sedimentary deposits, especially that of hardening and crystallising them, converting shale into slate, charring coal to coke, anthracite, and plumbago, and inducing crystalline texture in limestones and calcareous rocks.

Vegetable Origin of Coal.—The vegetable origin of this substance is now admitted, and no doubt exists, that it consists of the vegetation of the ancient earth, which has been buried beneath waters, and has either been submerged

* Mr. Sopwith has executed some beautiful models, which exhibit, in the most instructive manner, the stratification of the coal and the accompanying deposits; and has thus depicted the coal measures of the Forest of Dean, by means of sliding tables, which display the amount of coal, both wrought and unwrought, as well as of the ironstone which accompanies it. These models may be procured of Mr. Tennant, No. 149, Strand.

on the place of its growth, or conveyed to estuaries or the mouths of rivers, and sunk in spots alternately occupied by fresh and salt waters, where, under the influence of heat generated by chemical action, and the pressure of the mud, sand, or clay deposited by these streams, the vegetable masses have been converted into coal. The agency by which this result has been effected is supposed to have been analogous to the chemical process by which vegetable matter is known to ferment and produce spontaneous combustion. If hay be stacked in a moist condition, or too closely packed, fermentation and ignition are produced, and the mass is consumed; if the process be interrupted and combustion prevented, the hay is found to have acquired a dark brown colour, a glazed or oily surface, and a bituminous odour. The same phenomena are observed in the case of flax, which if packed and pressed in a damp state, is liable to the same results; all vegetable substances, under like conditions, being exposed to similar chemical changes. Were any vegetable matter, in a moistened state, placed beneath great pressure, so as to prevent its gaseous elements from escaping, bitumen, lignite, or coal would be produced during the various stages of the process. Vegetable matter has been traced through every stage of the saccharine, vinous, acetous, and bituminous fermentation; and alcohol, ether, naphtha, petroleum, bitumen, lignite, jet, coal, amber, and even the diamond, have been ascertained to be of vegetable origin.

Experiments of Göppert.—The experiments of Professor Göppert, of Breslau, which have been followed in this country, would alone be sufficient to establish the vegetable origin of coal, even if it were not already proved beyond the possibility of a doubt. Having observed that the leaf, in ironstone nodules, might occasionally be separated, in the form of a carbonaceous film, he placed fern-leaves in clay, dried them in the shade, exposed them to a red heat, and thus obtained striking resemblances to fossil plants. According to the degree of heat, the plant was found to have become either brown, shining, black, or to be entirely lost, the impression only remaining; but in this latter case, the surrounding clay was stained black, thus indicating that the colour of the coal-shales is derived from the carbon of the plants which they include.

Mode of Deposit of Coal.—Although the vegetable origin of coal is admitted, a considerable difference of opinion prevails as to the circumstances under which it has become imbedded in its present position. The idea usually entertained is, that groves and forests of the luxuriant vegetation of an ultra-tropical climate were swept away by floods and inundations into lakes, bays, estuaries, or the mouths of rivers; while the instances are few in which the coal plants grew and were submerged on the spot; it was considered, that drift was the rule, and submergence the exception. An opinion the reverse of this has recently been expressed, that while the greater part of the vegetable elements of coal have grown and been imbedded on the spot, the cases where the plants have been drifted are chiefly the accidental results of the overflows and inundations by which the submersion was effected. The following objections may be urged against the theory that coal was formed by drift:—

1. The purity of coal, and its freedom from extraneous substances. Had it been drifted, it must have acquired some portion of foreign substances in its transit, such as pebbles, gravel, &c.; but, since we find extensive seams of coal unmixed with any other matters, its freedom from these is considered to be incompatible with the idea of its having been drifted from a distance.

2. The generally uniform thickness of each coal-seam is considered to offer another difficulty. The lower main seam of the great northern coal-field, according to Mr. Bowman, extends over at least 200 square miles, while a thin seam is pointed out as reaching in a straight line from Whaley Bridge to Blackburn, a space of thirty-five miles. Had the coal been washed away by floods or torrents, such currents, either from the different specific gravity of portions of the same mass, of the roots and stems, for example, as contrasted with the branches and foliage, or from the mechanical obstructions occurring in such a transit, would have deposited them in an unequal manner; whereas, no such effects are observable in the coal-seams, which are invariably free from inequalities of this kind.

3. The exceeding minuteness of many of the coal-seams, which thin-out into mere filaments, and extend, in this condition, over extensive areas of solid rock, militates against

the idea of any deposit of so attenuated a nature having been spread over spaces so large by the act of drifting.

4. On the other hand, the size of many of the coal-seams, considered with reference to the immense compression which they have unquestionably undergone, is considered to furnish another objection of insurmountable character. The enormous extent to which the bulk of substances may be reduced by pressure, can scarcely be imagined, except by a reference to exact computation. It was ascertained by Mr. Burr that a mass of rubbish which was left in a worn-out vein of ironstone, during a period of two years, was in that interval reduced from seven to two feet in thickness, owing to the pressure of the overlying weight. It was further changed into so hard a substance, as to form a mass of rock, which could only be penetrated by the operation of blasting. When we consider the great compressibility of vegetable matter, and reflect that beds of coal have been subject to the pressure of masses of rock many thousand feet in thickness during a period of countless ages, and when we recollect that matter so compressed has formed beds of great relative thickness, it is evident that, for the formation of such deposits, supplies on the most enormous scale would be required, and that it would be utterly impossible to transport masses of vegetable substance so immense as would be requisite for the formation of the coal deposit alone.

5. The high state of preservation in which many of the plants occur, the perfect condition of the leaves, and parts of fructification of many of the ferns, the sharp angles of numerous stems which are presumed to have been of a soft and succulent nature, with the surfaces of *Sigillariæ* marked with lines, streaks, and flutings, so delicate that the mere drifting of a day would have inevitably destroyed them, together with the occurrence of fruits, such as *Cardiocarpon* and *Lepidostrobus*, which are found in heaps and clusters, whereas a current would have dispersed them,—these, with other facts of a like nature, convince us that these plants have never been subjected to drift, but were buried on the spots where they lived and died.

6. An additional objection to the drift theory is founded on chemical facts; it has been urged, that if vegetable matter were swept away by a flood, such an agency, by

allowing the gaseous elements to escape, would be inadequate to produce the desired results, and that coal never could be formed by such a process. The very close analogy presented by peat to lignite and coal affords a striking corroboration of the justice of such a view.

7. The multiplied instances of trees found erect establish the fact of the coal plants having chiefly grown on the spot where they are now entombed. Not only has Mr. Hawkshaw discovered the group of trees already described, on the line of the Bolton and Manchester Railway, but Mr. Conway, on forming the railway tunnel at Claycross, five miles south of Chesterfield, found a number of fossil trees, apparently *Sigillariæ*, no fewer than forty in number, standing not less than three or four feet apart, and forming a perfect fossil forest. When we reflect on the accidental nature of these discoveries, it is impossible to resist the conviction that the earth may contain innumerable forests entombed on the spots where they grew, many of which the progress of discovery will bring to light.

The idea of submergence is not new. Opinions which go to the support of this theory have been long expressed by Count Sternberg, Adolphe Brongniart, Lindley and Hutton, Hawkshaw and Bowman.

Mr. Logan,* in a highly interesting communication on the coal strata of South Wales, states that there is no instance in that district of any seam of coal without a bed of underclay abounding in *Stigmaria ficoides*, a marshy plant which existed in such abundance as to have formed, as he conjectures, the chief source of our fossil fuel. In a second communication, on the coal-fields of Pennsylvania, he states that the same phenomenon of the underclay prevails throughout those deposits.

So much light has been thrown on the formation of coal by these and similar observations, that an opinion now prevails that the vegetation which produced the coal grew in broad and shallow lagoons or sheets of water, receiving at intervals deposits of silt and mud, the detritus of neighbouring land. These streams were speedily filled up by the growth of a profusion of *Stigmariæ*, until, by the accumula-

* See Proceedings of Geological Society, vol. iii., No. 69, p. 275.

tion of mud, silt, sand, and the admixture of decayed vegetable matter, the lagoon was converted into a morass. A

FIG. 295.— Virgin Forest, Isle of Gouahan.

fresh vegetable growth now ensued, of a somewhat different character, consisting of reed-like plants, *Equiseta* and *Cala-*

mites, with here and there a larger tree. The spoils of these plants may have furnished materials for beds of peat and coal, resting on a base composed of the remains of *Stigmariæ*. The lagoon or the morass, by repeated subsidences, may have sunk beneath the level of the sea, and have rendered the basin the receptacle of alternating deposits of sand and clay, and may thus have produced the strata of sandstone and limestone which occur between seams of coal. As each deposit was formed, it may have been covered either wholly or in part by a lagoon, when the same succession of vegetable growth and deposit may have ensued.

The alternation of beds of coal with marine deposits is explained by the supposition that an extensive subsidence of the estuaries, which were the site of the lacustrine and

FIG. 296.—Section showing the erect position of fossil trees in coal sandstone at St. Etienne. (A. Brongniart.)

terrestrial vegetation, may have reduced them beneath the level of the sea, where the submerged soil with its vegetation was covered with marine sediments; in course of time, either by drifts of sand or clay from the land, or by the elevation of the bed of the sea, the estuaries were again filled, and became the area of the vegetable growth above named, while the repetition of such changes would account for the alternation of marine and lacustrine strata which occur in beds of

coal. Fig. 295, representing a virgin forest of the Isle of Gouahan, one of the Mariana Islands, will enable the student to form an idea of the character of the vegetation which is supposed to have produced the coal-fields.

Erect Fossil Trees.—These have been found in various parts of the Continent as well as of this country. At St. Etienne, near Lyons, a fossil forest appears, the stems of the trees standing nearly vertical. (Fig. 296.)

A single tree was discovered some years since, at Craigleith, in a sandstone quarry, near Edinburgh. (Fig. 297)

Fig. 297.—Inclined position of a fossil tree in a sandstone quarry near Edinburgh. Angle of inclination, 27°.

Those discovered by Mr. Hawkshaw on the Bolton and Manchester railway are here figured. (Fig. 298.)

The following description will afford an idea of their position, appearance, and general characters. Another tree has subsequently been discovered on the opposite side of the railway, making the entire number six. The section of the strata gives the following as their order and composition. 1. Sand, intermixed with patches of loam; 2. An intermixture of argillaceous and siliceous shales; 3. Siliceous shale; 4. A vein of coal, two feet in thickness; 5. Blue and white argillaceous shale, in which the trees are embedded. The five trees are nearly in a straight line, and being parallel to the direction of the railway, they stand obliquely across the

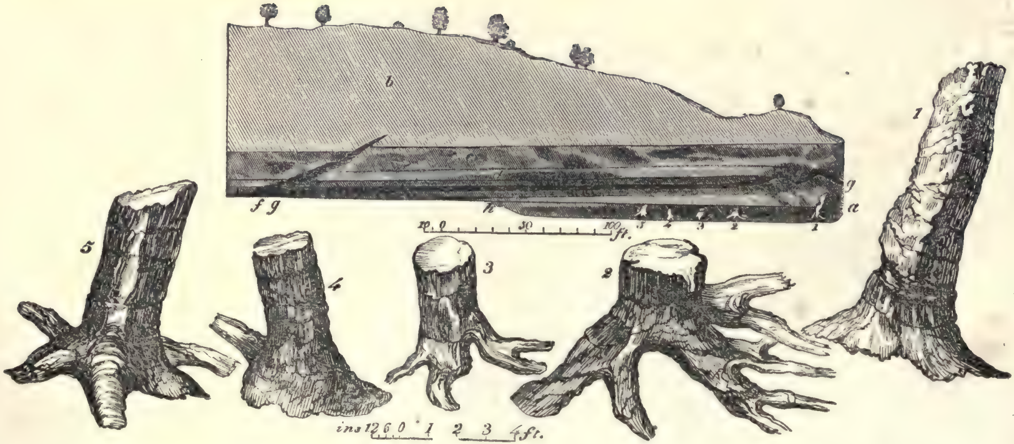


FIG. 298.—Erect Fossil Trees, on the Bolton and Manchester Railway. *a.* The trees. *b.* Stratification above the fossils, of sand intermixed with patches of loam. *c, d,* and *e.* Consisting of thin beds of shale. *f.* A fault filled with shale. *g.* A seam of coal, two feet thick.

dip of the strata. In the direction of the section, a line drawn through the root of the trees is conformable to the inclination of the strata; and in the direction of the new dip, this is still more plainly the case; the large spreading roots of Nos. 2 and 5 being quite conformable to the inclination of the stratum in which they rest; and the roots of the others are equally so, to the extent to which they are seen, but being less exposed, they are not so evident in this respect. The whole of the stems stand nearly at right angles to the plane of stratification. They are imbedded chiefly in a soft, argillaceous blue shale, but that which surrounds the upper end of No. 1 is of a more siliceous nature. In the same plane as the roots, a thin stratum of coal has been found as far as the excavations have extended. The trees, when discovered, had each a coating of coal, which was so friable that it crumbled to pieces in removing the shale. It is supposed to have been the bark of the trees carbonised, since they now appear completely decorticated, and present various flutings. The largest, No. 1, is about fifteen feet in circumference at its base, seven feet and a half at its top, and eleven feet in height. The next, No. 5, is seven feet and a half in circumference, and two feet and a half in height; while Nos. 3 and 4 are of smaller size, being respectively three and five feet in height and six in circumference.

EXERCISES

ON THE CARBONIFEROUS GROUP.

1. Name the authors and collections.
2. Mention the chief characteristics of the group.
3. State the usual arrangement of the beds.
4. Describe the chief coal-fields of England.
5. Explain the origin of coal.
6. Describe its deposition by subsidence, and state the reasons for ascribing it to this agency, rather than to drift.
7. Explain the nature of its vegetation.
8. Describe the character of its climate.
9. State any general phenomena, and pursue the accustomed method of question and answer.

CHAPTER XVIII.

THE MOUNTAIN LIMESTONE.

The Carboniferous or Mountain Limestone of English; Calcaire Carbonifère, Calcaire Anthracifère, Calcaire de Transition of French Authors.

Museums:—Geological Society; Bristol, York, and Dudley, Institutions; Collection of Mr. Gilbertson, now transferred to the British Museum; that of Dublin, &c.

Authors:—Martin, Miller, Sedgwick, Phillips, Murchison, Conybeare.

Characteristics:— A Marine deposit, abounding in Zoophytes (chiefly Crinoidea), Shells, Fishes, and other marine exuviæ, remarkable for the abundance and variety of its mineral productions, its caverns, and fissures.

The practice of bestowing new names on objects familiar to science, is neither commendable nor useful; yet the formation we are about to describe seems to require some more appropriate appellation than that by which it is usually distinguished. The term carboniferous properly signifies "bearing coal," whereas this limestone, with perhaps the single exception of the Berwickshire coal-field, never contains that substance; while the name mountain-limestone is equally ill bestowed on a rock, which, both in this country, Ireland, and on the Continent, frequently occupies valleys.

Geographical Distribution.—It is extensively developed over the northern and western parts of England, in Derbyshire, Shropshire, Somersetshire, and Gloucestershire, lying between the coal and the more ancient rocks beneath. In Cumberland and Westmoreland it attains considerable elevations, partly encircling the mountains of slaty rocks: while in Derbyshire and Yorkshire it rises to independent peaks and hills, presenting scenery of the wildest and most picturesque character.

Mineral Productions.—These are more abundant in this formation than in any hitherto described. The rock itself is of sub-crystalline texture, and is susceptible of a high

polish. Fluor-spars occur abundantly in veins in the vicinity of Castleton, and the manufacture of this substance into cups, vases, &c., constitutes a local branch of industry of considerable importance. Manganese, copper, zinc, barytes, and iron, also exist in this formation; but the most abundant ore is the sulphuret of lead or galena, of which there are several extensive mines.

Organic Remains.—These consist of an abundance of corals, chiefly of the genera which form coral reefs: there

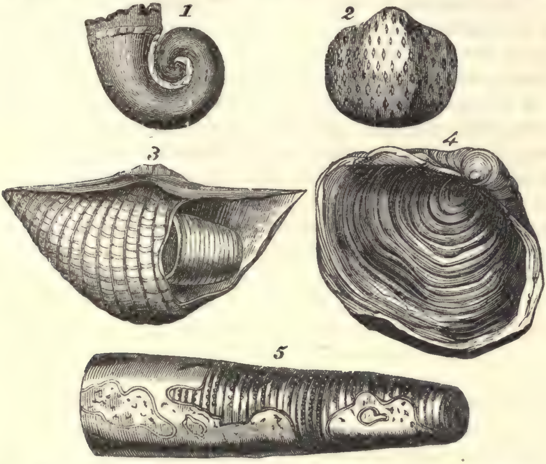


Fig. 299.—Bellerophon cornu-arietis. 2. Producta scabricula. 3. Spirifera trigonalis. 4. Producta punctata. 5. Orthoceras undatum.

are also great numbers of crinoidea, the débris of which make up extensive beds of limestone. Of the conchiferous mollusca the prevailing genera are *Spirifera* and *Producta.* Of cephalopoda, the prevalent genera are *Orthoceras, Goniatites*, and *Nautilus.* The *Orthoceras* was a chambered shell, like a *nautilus*, but uncoiled and straight: the *Goniatites* have the borders of the septa free from denticulations. The *Euomphalus* is an extinct genus of univalves, extremely abundant in this limestone. The interior is often divided by septa, but the partitions of these chambers are not

perforated as in forameniferous shells, or in those which have a siphuncle, like the nautilus. The *Bellerophon* was long considered to be the shell of a cephalopod, but as it has no septa, it is now classed among the gasteropoda; it was very prevalent in the carboniferous seas. The plate 299 contains figures of some of the most common shells of this group. The crustacea were represented in the carboniferous fauna; small Cyproidæ, belonging to the genera, *Cythere*, *Cypridina*, and *Cyprella*, with *Limulus*, *Apus*, and *Trilobites* are found. Air-breathing articulata have likewise been obtained; a scorpion was discovered by Count Sternberg in the coal formation near Prague, which furnishes another proof that, during this epoch, the centre of Europe had a temperature similar to that which characterises the intertropical regions of the present day. Coleopterous insects, belonging to the family *Curculionidæ* and neuroptera, of the genus *Corydale*, have been found at Coalbrook Dale, and in Germany several species of orthoptera. The mountain limestone of Bristol has yielded some fine specimens of ichthyolites, as the teeth and ichthyodorulites of Placoid fishes; the heterocercal Lepidoid fishes, as *Amblypterus* and *Palæoniscus*, and the heterocercal Sauroids, as *Megalichtys* and *Acrolepis*, are found in this formation, with many other families and genera which our limits compel us to omit from the enumeration.

Professor Von Dechen found in the coal-field of Saarbrück three species of reptiles referred by Goldfuss to the genus *Archegosaurus;* the skulls, teeth, and portions of the skeleton have been found. The true position of these ancient reptiles has not been determined; they are supposed to be nearly related to the *Labyrinthodon;* their tegumentary covering consisted of long, narrow, wedge-shaped, tile-like, horny scales, arranged in parallel rows. Footprints of reptiles have been discovered in the coal strata of the United States.

Caverns.—The mountain-limestone is remarkable for the extensive caverns which prevail in the strata of some regions, as those of Derbyshire, Devon, Somerset, and various parts of Ireland. Many of these are the channels of subterranean streams, which are conducted into them through fissures in the strata.

These caverns are also remarkable for the *stalactites* and *stalagmites* they contain. The explanation of these phenomena is as follows:—The water, flowing through limestone rocks, dissolves a portion of the lime, and on reaching an opening, such as a cavern, at its sides or roof, it forms a drop, the moisture of which evaporates, and leaves a small circular plate of calcareous matter, which is increased by the constant dropping of the water. In process of time continual accumulations of this nature form long pendent points like *icicles;* for a *stalactite* may be said to be an *icicle* of stone, as an *icicle* may be said to be a *stalactite* of frozen water. When the supply of water holding lime in solution is too rapid to allow of its evaporation at the bottom of the *stalactite*, it drops to the floor of the cavern, dries up, and forms in like manner a *stalactite* rising from the ground, which, for the sake of distinction, is termed a *stalagmite*, Where the two unite, they form natural columns. The most celebrated caves of this kind are the Grotto of Antiparos, in Greece; that of Adelsberg, in Styria; and Weyer's cave, in the United States.

EXERCISES

ON THE CARBONIFEROUS OR MOUNTAIN LIMESTONE.

1. State the characteristics of the formation.
2. Point out its geographical distribution.
3. Trace its course on the map.
4. Name the localities in which it prevails.
5. Describe its organic remains.
6. Mention its mineral contents.
7. State any facts of general interest, and pursue the method of question and reply as before.

CHAPTER XIX.

THE DEVONIAN GROUP.

Old Red Sandstone, or Devonian System, of English Authors; Grès Rouge Intermediate, of French; Grauwacken-Gebilde, of German Authors.

Museums:—British Museum; Geological Society; various Collections in Scotland.

Authors:—Miller, Murchison, Sedgwick, Boue, De Verneuil, Agassiz.

Characteristics:—A Marine deposit, chiefly remarkable for its Fossil Fishes.

This group affords a striking illustration of the progressive nature of geological inquiry. Up to a recent period, the old red sandstone was regarded as a subordinate member of the carboniferous series, and from its supposed paucity of fossils was usually passed over in silence and neglect.

Owing, however, to the researches of modern geologists, and in particular of that distinguished observer by whom the Silurian rocks have been raised to the rank of a distinct system, the Devonian has been found to form an important group in the palæozoic series, characterised by a well-developed and distinctly defined fauna.

The name is derived from the circumstance of this group being extensively developed in Devonshire. A triple subdivision has been proposed by Sir R. Murchison.*

I. Quartzose Conglomerates and Sandstone.

(a). The upper beds consist of quartzose grits, with a slight calcareous cement, or pink and reddish quartzose conglomerates, passing—

(b). Downwards into chocolate, brown, and reddish, coarse-

* Silurian System, page 170, *et seq.*

grained sandstone, with alternating bands of red and green argillaceous marls.

(a). The picturesque cliffs of Symond's Yat, between Monmouth and Ross; on the right bank of the Wye, to the north of Tintern Abbey; and along the summit of Wentwood, between Chepstow and Usk.

(b). The Fan bwlch-y-chwyth, near Trecastle; the Daren, two miles north of Crickhowell.

Fish—*Holoptychius nobilissimus.*

II. Cornstone and Marl.

Red and green argillaceous and spotted marls, with alternating bands of sandstone, or with irregular courses of concretionary impure limestone (Cornstone), mottled, red, and green.

The cliffs under the castle at Lanstiphan, near the mouth of the Towy; in the vicinity of Hay; and in the valley of the Usk, near Abergavenny.

Fishes—*Cephalaspis* and *Onchus.*

III. Tilestone.

Finely-laminated, hard, reddish or green, micaceous, quartzose sandstones, which split into tiles; with occasional beds of reddish shale.

In the gorge of the Teme, between Ludlow and Downton Castle, near the Tin Mill; Oakley Park, Ludlow. Horeb Chapel; the valley of the Cwm Dwr, between Trecastle and Llandovery.

Fishes—*Dipterus, Onchus,* and various genera of *Mollusca.*

In Scotland this system is also largely developed, in Caithness and Cromarty, as described by Mr. Miller;* in Dura Den, south of Cupar, in the valley of Strathmore and adjacent district, as observed by Sir C. Lyell.†

* Hugh Miller, Old Red Sandstone.

† Elements of Geology, vol. ii., page 148.

The thickness of the English group is estimated on an average at 10,000 feet, but in Scotland it is conjectured to be much greater. In addition to the localities given in the above table, it is largely developed in the south of Devon, in Shropshire, Herefordshire, and the border-counties of Wales; on the Continent it occurs in Germany, and extends over vast areas in Russia, south of St. Petersburgh.

Identity of the old Red Sandstone of Hereford and Devon.—Doubts were entertained for a considerable period as to whether the old red sandstone of Devon and that of Hereford were identical; these doubts being chiefly suggested by the fact that the strata of Devon contained shells of the genera *Orthis*, *Spirifera*, *Productus*, *Terebratula*, &c., which were not found in the rocks of Hereford; whilst the latter afforded fishes which were not found in those of Devon. Sir R. Murchison, however, in his first visit to Russia, in 1840, discovered, in strata appertaining to the old red sandstone, the fishes of Hereford and Scotland, in the same beds with the shells of Devon. Sir R. Murchison and Professor Sedgwick have further shown that the equivalents of the Devon rocks exist in the Rhenish provinces, and adjacent parts of Germany. Certain corals, as *Cyathophyllum cæspitosum*, *Porites pyriformis*, and *Favosites polymorpha*, with the shells *Megalodon cucullatus*, *Calceola sandalina*, and *Strygocephalus Burtini* are characteristic of the rocks of Devon, and of the Eifel in Germany.

Among the gasteropoda are species of *Pleurotomaria*, *Euomphalus*, *Bellerophon*, *Nerita*, and *Natica*, &c.; the cephalopoda are represented by the genera *Aganides*, *Clymenia*, *Gyroceras*, *Cyrtoceras*, *Stenoceras*. The articulata of this group belong to the family of Trilobites. The rocks of Devon have yielded specimens of *Calymene*, *Asaphus*, *Harpes*, *Homalonotus*, and *Brontes*, one species of which (*B. flabellifer*) is common to the Devonian rocks of the Eifel and South Devon.

This group is well developed in Germany: the limestones of the Eifel, so long celebrated for their fossil remains, belong to the lower part of this system, and lie in a basin supported by Silurian rocks.

In Russia the Devonian system occupies a wide area south of St. Petersburgh, and contains a fauna similar to

that which characterises this group in our island, containing fishes of the genera *Holoptychius*, *Coccosteus*, *Diplopterus*, &c., associated with mollusca of the same genera as those found in the Devonian rocks in Western Europe.

The Devonian group is well developed in the United States at the Falls of the Ohio. At Louisville, in Kentucky, Sir Charles Lyell * states that "there is a grand display of one of the limestones of this period, resembling a modern coral reef. A wide extent of surface is exposed in a series of horizontal ledges, at all seasons when the water is not high; and the softer parts of the stone having decomposed and wasted away, the harder calcareous corals stand out in relief, and many of them send out branches from their erect stems, precisely as if they were living. Among other species large masses, not less than five feet in diameter, of *Favosites gothlandica* were observed, with its beautiful honeycomb structure well displayed; and, by the side of it, the *Favistella*, combining a similar honeycombed form with the star of the *Astræa*. There was also the cup-shaped *Cyathophyllum*, and the delicate net-work of the *Fenestella*, and that elegant and well-known European species, the 'chain coral,' *Catenipora escharoides*, with a profusion of others. These coralline forms were mingled with the joints, stems, and occasionally the heads, of encrinites."

FOSSIL FISHES.—The most prevalent organic remains contained in the subdivisions of this group in Scotland consist of fossil fishes, belonging to the genera *Holoptychius*, *Cephalaspis*, *Pterichthys*, *Coccosteus*, *Diplopterus*, *Dipterus*, and *Cheiracanthus*. Eight species of *Pterichthys* (or winged fish) are known. Fig. 192 represents the under-surface of one of these. The singular fins, with their strong points and oar-like blades, were weapons of defence, which, like the occipital spines of the river bull-head (*Cottus gobio*), were erected in moments of danger or alarm, and at others lay close to the creature's side; the tail being the sole instrument of motion.

The genera *Dipterus* and *Diplopterus* are thus named, because their two dorsal fins are so placed as to front the anal and ventral fins, and appear like two pairs of wings.

* Manual of Elementary Geology, Third Edition, p. 349.

Figure 191 represents the *Coccosteus*. This remarkable fish had a large head, covered with osseous plates, the mouth armed with small conical teeth, and the body terminated in a long flexible tail; it possessed an anal and dorsal fin, but had no pectorals; three species are known. For a most interesting and graphic description of these fishes, the student should consult Mr. Millar's work, already quoted, and especially the able monograph by Professor Agassiz, on the fishes of the old red sandstone.

EXERCISES

ON THE DEVONIAN GROUP.

1. Describe the authors and collections.
2. State the general characteristics.
3. Mention its geographical distribution.
4. Describe its organic remains, and follow the usual method of question and reply.

CHAPTER XX.

THE SILURIAN GROUP.

Silurian System of Sir R. Murchison and English Authors; Systèmes Quartzo-Schisteux supérieurs et inférieurs of M. Dumont; Palæozoic Rocks of Authors.

Museums:—Geological Society; Museums of Dudley, Ludlow, &c.; Collection of Sir R. Murchison, Mr. Grey, and of other Local Collectors.

Authors:—Murchison, De Verneuil, Dumont, Barrande.

Characteristics:—A Marine deposit of vast extent containing a number and variety of Marine organic remains.

This group, which was formerly imperfectly known, and classed under the general denomination of grey-wacke or transition rocks, has been most ably investigated by Sir R. Murchison, to whose great work on the subject we must refer for complete details. The name of Silurian has been bestowed on this group in consequence of the districts which it occupies in this country being those formerly inhabited by that tribe of the ancient Britons named the Silures.

Geographical Distribution.—The Silurian strata extend from the heart of South Wales to that of England, over the counties of Radnor, Montgomery, Caermarthen, Brecon, Pembroke, Monmouth, Gloucester, Worcester, Hereford, and Shropshire. They are classified into two divisions, the Upper and Lower Silurian, which are again subdivided into two upper and two lower stages.

UPPER SILURIAN ROCKS.

1. Ludlow formation.	1. Upper Ludlow.	Micaceous grey sandstone.	Containing shells of every class, brachiopoda most abundant, corals and sauroid fish. Thickness 2000 feet.
	2. Aymestry limestone.	Argillaceous limestone.	
	3. Lower Ludlow.	Strata with concretionary limestone.	
2. Wenlock formation.	1. Wenlock limestone.	Concretionary limestone.	Shells as before, trilobites, fishes. Thickness 1800 feet.
	2. Wenlock shale.	Argillaceous shale.	

LOWER SILURIAN ROCKS.

3. Caradoc formation.	Caradoc sandstones.	Flags of shelly limestone and sandstone with white freestone.	Crinoidea, corals, mollusca, chiefly brachiopoda, trilobites. Thickness 2500 feet.
4. Llandeilo formation.	Llandeilo flags.	Dark coloured calcareous flags.	Mollusca and trilobites. Thickness 1200 feet.

I. Upper Silurian Rocks.

The Upper Ludlow.—The first member of the upper series consists of a grey calcareous sandstone containing the spines, scales, and teeth of fishes of the genera *Sphagodus*, *Pterygotus*, *Plectrodus*, *Sclerodus*, *Thelodus*, and *Onchus*. The shells belong to the genera *Avicula*, *Cypricardia*, *Leptæna*, *Atrypa*, *Orthis orbicularis* (1), and *Terebratula navicula* (2), (fig. 300), are very abundant in some beds.

The *Aymestry limestone* consists of a subcrystalline argillaceous limestone, about fifty feet thick, in which *Pentamerus Knightii* (4) is very abundant; it also occurs in the lower Ludlow: this singular brachiopod was found in myriads, dispersed through a white limestone of the upper Silurian group on the banks of the Is, on the eastern flank of the Urals, in Russia. The Aymestry limestone contains, likewise, *Lingula Lewesii*, *Terebratula Wilsoni*, and *Atrypa affinis* (5); the latter shell has a wide vertical range, being common to all the Silurian stages, the Llandeilo flags excepted.

The Lower Ludlow Shale consists of a dark grey argillaceous deposit, containing *Graptolithus Ludensis*, a form of Silurian zoophyte, supposed to be allied to the *Pennatula*, or sea-pen of our seas; here, likewise, are found *Orthoceras Ludensis*, *Lituites giganteus* (7), and *Phragmoceras ventricosum* (6), (fig. 300.) *Homalonotus delphinocephalus* (fig. 176) is the trilobite common to this stage and the Wenlock limestone, and is remarkable for having the longitudinal furrows of the carapace nearly obliterated, and forming a type of this singular family of crustacea, which is special to the Silurian rocks.

The Wenlock Formation.—The lower division, comprising the Wenlock formation, is subdivided into two portions, the upper being the Wenlock, or Dudley limestone, and the lower the Wenlock shale. Its characteristic fossils are

Phacops caudatus, and *Calymene Blumenbachii*, together with corals of the genera *Catenipora*, *Porites*, and *Cystiphyllum;* the organic remains partake rather of the character of the lower Silurian formations beneath, than of the Upper Ludlow above.

The Wenlock Shale contains many fossils; among the corals, *Cystiphyllum* and *Porites* prevail; the brachiopods are represented by the genera *Lingula* and *Atrypa;* many of the other Silurian species extend into this shale, which attains a thickness of 700 feet.

II. The Lower Silurian Rocks.

These have been subdivided into two portions, the Caradoc sandstone and the Llandeilo flags: the former is best developed in the vicinity of the Caradoc hills, in Shropshire; the latter in Caermarthenshire.

The *Caradoc sandstone*.—The characteristic fossils of this rock consist of various species of *Atrypa*, *Leptæna*, *Orthis*, *Pentamerus*, *Bellerophon*, and *Orthoceras*, with *Tentaculites*, supposed to be the sheath of a worm nearly allied to *Serpula*. In the Caradoc of Gloucestershire many beautiful corals are found.

The *Llandeilo flags*.—These contain, as their characteristic shells, several species of *Euomphalus*, *Lituites*, &c., gigantic trilobites, *Asaphus Buchii*, and *Asaphus tyrannus*, with numerous smaller forms belonging to the genus *Trinucleus*. In the fine shales of this formation Graptolites are very abundant.

Distribution of the Silurian Group.—The Silurian strata have been discovered in various parts of the Continent. Sir R. Murchison found them in Belgium, the banks of the Rhine, Westphalia, and Nassau; in the north of Germany, the extreme parts of Russia, and at the very confines of the old world; the American geologists have shown that they are extensively developed in the lake region of North America.*

* In his great work on the Silurian System, Sir R. Murchison has given a profusion of sections, numerous beautiful plates of fossils, and a large geological map of the Silurian region of England and Wales

The accompanying illustration contains figures of a few of the most prevalent Silurian shells. (Fig. 300.)

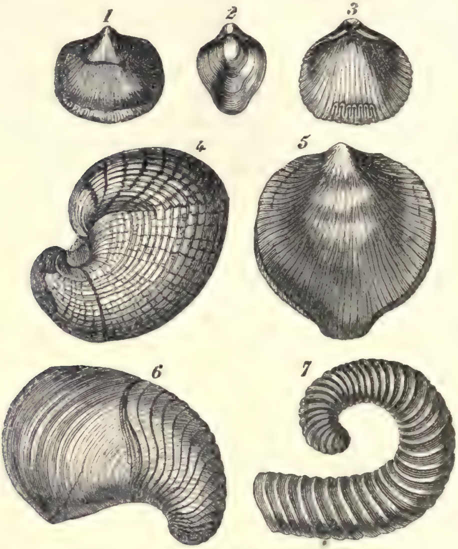


FIG. 300.—1. Orthis orbicularis. 2. Terebratula navicula. 3. Orthis navicularis 4. Pentamerus Knightii. 5. Atrypa affinis. 6. Phragmoceras ventricosum. 7. Lituites giganteus.

CAMBRIAN AND CUMBRIAN GROUPS.

THE CAMBRIAN GROUP consists of a vast series of rocks, of a slaty character, in some of which fossils have been found. The upper beds of Snowdon contain two species of corals (*Cyathophyllum*) and six of the older forms of *Terebratula.* Professor Sedgwick divides this group into the

Plynlymmon rocks.—Argillaceous indurated rocks, sandy or slaty.
Bala limestone.—Dark laminated limestone and slate.
Snowdon rocks.—Fine and coarse-grained slaty rocks.

THE CUMBRIAN GROUP.—The Fossiliferous slates of the

Lake district extending from the Coniston Limestone to the valley of the Lune, are divided into five formations.

5. Upper Slate of Kendal.	c. Greenish Grey and Red Flagstones. b. Grits and Slates, with Upper Ludlow Fossils. a. Coarse Slates passing into No. 4, d.
4. Ireleth Slates . .	d. Coarse Slates, Flags, and Grits, with *Terebratula navicula*, and Upper Ludlow Fossils. c. Upper Ireleth Slates. b. Calcareous Slates and Limestones. a. Lower Ireleth Slates.
3. Coniston Grit . .	*Graptolithus, Cardiola, Orthoceras.*
2. Coniston Brathay Flagstone.	*Graptolithus* and Upper Silurian Species.
1. Coniston Limestone.	Lower Silurian Fossils.

Whether the Cambrian and Cumbrian rocks, which we have described above from Professor Sedgwick's researches, form a distinct system, or only a portion of the Silurian group, we have not at present sufficient data to enable us to determine; we have therefore placed them in a separate section at the close of the present chapter. So much has been done by our distinguished countrymen, Murchison and Sedgwick, in the department of Palæozoic geology, that we have still much to hope from their further researches into this most ancient epoch of the earth's history. D'Orbigny describes 845 species of animals from the Silurian system, of which 418 belong to the upper, and 427 to the lower divisions. Of the 418 upper Silurian species, 356 are Mollusca, and 61 are Radiata; of the 427 lower Silurian species, 375 belong to the Mollusca, and 52 to the Radiata. The Silurian system of Bohemia has, for the last ten years, engaged the attention of M. Barrande, who has discovered the astonishing number of 1100 species of invertebrata in the Silurian rocks of that region; whereas, from the same area, about 20 species only had been previously described. Of the 1100 species he finds:—

Crustacea, chiefly Trilobites	250	species.
Cephalopoda	250	„
Gasteropoda and Pteropoda	160	„
Conchifera	130	„
Brachiopoda	200	„
Zoophyta	110	„
	1100	

These fossils were obtained from a superficial area, not more extensive than one-sixtieth part of the Adriatic; proving thereby, that the Silurian fauna was not only as rich but as much influenced by geographical conditions as that of any subsequent epoch. The perfect condition of many of these fossils enabled this naturalist to collect a series of the different forms which species assume in the course of their development; specimens illustrating the metamorphosis of nineteen species of Bohemian trilobites belonging to ten genera, have been obtained. M. Barrande has shown that one species, known as *Sao hirsuta*, presents twenty different forms; out of which former palæontologists have made eighteen species, distributed in ten genera. These important researches have established the interesting fact conjectured by other naturalists, that the *Trilobitidæ* passed through a series of embryonic forms between their egg-life and mature condition, just as the crustacea of our rivers and seas do at the present time. A stratigraphical arrangement of the Bohemian fossils further proves a series of changes in organic life corresponding in chronological order, to those of equivalent groups previously established for the classification of the Palæozoic strata of Europe and North America.*

EXERCISES

ON THE SILURIAN AND CAMBRIAN GROUPS.

State the various collections of these groups, the different localities of their beds, their general characteristics, geographical distribution, and principal organic remains; and practise the usual mode of question and reply.

* Sir C. Lyell's Anniversary Address, 1851.

CHAPTER XXI

THE METAMORPHIC AND PLUTONIC ROCKS.

METAMORPHIC ROCKS.—Our chapter on Physical Geology has so far tended to explain the character and origin of these rocks, that a lengthened detail in this place would rather embarrass than assist the student: a brief recapitulation of their most important characters will suffice for the present purpose.

The best general idea, perhaps, which the student can form of these formations, is to regard them as possessing an intermediate position and character between the sedimentary rocks above and the Plutonic rocks below, with both of which they are intimately connected. They resemble the sedimentary rocks in the circumstance that they exhibit marks of stratification, many of the upper slaty beds passing into overlying deposits of aqueous origin. On the contrary, they are allied to the Plutonic rocks beneath, by the circumstance of containing no organic remains; some of the lowest beds appearing to graduate into the underlying granite.

THE MICA-SCHIST SYSTEM.—Mica-schist is essentially composed of mica and quartz, the two minerals being disposed in alternate layers, forming laminated strata, which are extremely wavy and contorted. The upper beds approach the character of clay-slate, presenting laminæ of mica, chlorite, talc, and hornblende, together with limited beds of crystalline limestone, iron ore, &c.; the lower are of a more quartzose character, consisting of quartz and mica, quartz and chlorite, and quartz rock. The British localities are the Highlands of Scotland and the north-west of Ireland.

THE GNEISS SYSTEM.—Rocks of this character form the lower portion of the series. The gneiss itself is composed

of the same elements as granite (mica, quartz, and felspar), and these being arranged in undulated, or contorted layers, may be considered slaty granite. The system contains, in addition to beds of gneiss, mica-schist, quartz-rock, primary limestone, hornblende-schist, and clay-slate, alternating in a very irregular manner. If the gneiss and the mica-schist are regarded as sedimentary rocks, metamorphosed and rendered crystalline by heat, the change in the case of gneiss appears to have been but partial, this rock having been formed from the disintegration of granite, and deposited in its present form by an ocean which was, probably, too warm for the support of animal life. On the other hand, the gradation of gneiss into mica-schist and slaty rocks, and of these into others which are unquestionably of aqueous origin, strengthen the probability of the whole being of the common origin assigned them by Dr. Hutton, and owing their dissimilar physical characters to the unequal degrees of heat to which they have been exposed.* The stratification of

FIG. 301.—Vein of Porphyry, traversing argillaceous schist, St. Agnes, Cornwall.

gneiss is more or less distinct; the strata are often inclined to the horizon at a very great angle. Mountains composed of gneiss are seldom so steep as those of granite; and their

* Professor Phillips: Treatise on Geology, in the Cabinet Cyclopædia.

summits, instead of presenting needle-like points, are usually rounded. Gneiss is one of the most metalliferous of the primary rocks, its ores occurring both in beds and veins, but more frequently in the latter form. The localities in which gneiss occurs in this island are the north and north-western parts, and the Western Isles of Scotland.

THE PLUTONIC, OR MELTED ROCKS.—These are usually divided into two classes, the trap-rocks, comprising the basalts, porphyries, and their associate substances, and the granites and their kindred rocks. The trap-rocks commonly occur in the shape of veins or dikes, as shown in fig. 301, which represents a vein of porphyry, traversing argillaceous schist, at St. Agnes, Cornwall.

Their columnar arrangement is developed at the cave of Fingal, in the Isle of Mull. (Fig. 302.)

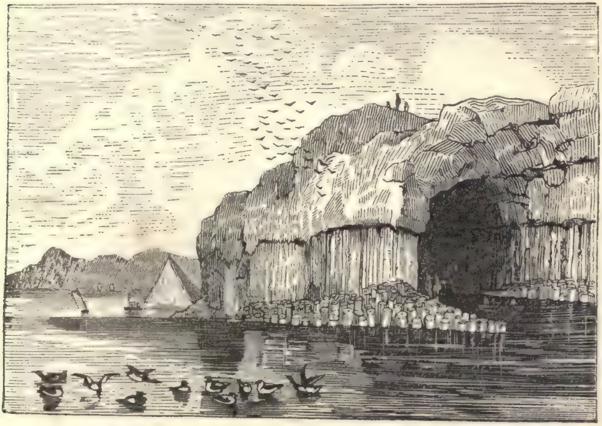


FIG. 302.—Basaltic Columns at the Entrance to Fingal's Cave.

The following illustration (fig. 303), portrays an instance occurring in the vicinity of Carlsbad, of a vein of granite traversing a mass of granite older than itself, and proving the different ages of this rock.

For more minute details we refer to the works of Hutton,

Playfair, Macculloch, and others; Mr. Wallace,* divides the granitic rocks into two classes; the first comprises granites,

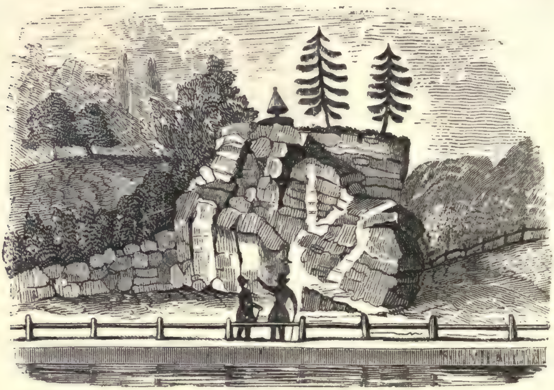


FIG 303.—Vein of Granite, penetrating a mass of granite older than itself, in the vicinity of Carlsbad.

in the composition of which the alkaline earths form no essential part; whilst in the second class, they are essential ingredients. The first class is divided into two orders; the first, called *perfect granite*, is a ternary compound of quartz, felspar, and di-axial mica, universally diffused, and generally coarse-grained, when found in masses; the second called *imperfect granite*, including the compounds of felspar and mica, without quartz, and of quartz and felspar, without mica. There is no binary compound of quartz and mica, as this would be incapable of assuming the granitic structure. The second class includes three orders: 1st, *hornblendic granite;* 2nd, *talcose granite*, or protogine; and 3rd, *schorly granite.* Each of these orders includes several varieties. Of these granites, the author regards the ternary, composed of quartz, felspar, and di-axial mica, as the lowest accessible rock of the earth's original crust, uplifted and protruded through sedimentary strata at different periods, from the earliest to the latest age of igneous disturbance. The fine-grained varieties of ternary

* Memoir read before the Geological Society.

granite, which are often found in veins, have probably been fused a second time. The seat of the binary granites was probably below that of the ternary rock, but higher than the granites, which contain alkaline earthy substances. The general conclusion is, that the absence of mica, or the presence of minerals abounding in magnesia or lime, or that of metallic oxides, or a transition into syenite, porphyry, basalt, or volcanic rocks, are indications of a later origin than that of ancient granite.

We have already described the classification of the primary rocks into a three-fold division, as the most natural arrangement, and have attributed their texture and aspect to the agency of fire; the metamorphic rocks are supposed to have been altered by its action, while the basalts and granites have been reduced by it to a state of fusion; the trap-rocks having been ejected from beneath, and the granites having crystallised, from a melted condition under the weight and pressure of the superincumbent strata. With reference to the granites, it may be observed, that mountains of this rock are usually extremely steep, and their summits present those notched or serrated edges, which, in the languages of the south of Europe, have occasioned the name of Sierra to be bestowed on hills of this character. We have already stated that granitic rocks occur as dikes and veins, which pierce the superincumbent strata, and occasionally penetrate to the top, spreading and towering over all they have displaced. We have also observed that veins of granite are frequently traversed by other veins newer than themselves (fig. 303); that granite is thus proved to be of all ages, and to have been fluid at the close of the secondary, and even during the tertiary epoch. We have also adverted to the fact, that it has been protruded in a solid as well as a fluid condition, and have instanced as negative proofs of its solidity when ejected, the absence of dikes or veins ramifying into the surrounding rocks, and of any marks of charring or calcining; and as positive evidence, the phenomena of rubbing and abrasion, and the masses of conglomerate and breccia occurring at the line of junction. We have farther alluded to the theory of Dr. Hutton, who supposed that the whole of the non-fossiliferous deposits, are not independent formations, but

merely so much sedimentary materials which have been fused by heat; in short, so many sandstones, limestones, clays, &c., which have first been melted, and then cooled to their present crystallised condition; that they are, in reality, no separate structure, but merely the pavement of that temple which the Almighty has filled with so many monuments of his wisdom, benevolence, and power.

DIRECTIONS

FOR

COLLECTING SPECIMENS OF GEOLOGY AND MINERALOGY,

FOR THE BRITISH MUSEUM.

BY C. KÖNIG, ESQ., KEEPER OF THE MINERALOGICAL DEPARTMENT.

THE following short directions being intended for the use of such persons as are supposed to be entirely unpractised in geology and mineralogy, all technical terms, the understanding of which pre-supposes an acquaintance with those sciences, have been carefully avoided; as likewise, all references to the relative order or superposition of rocks, and the succession in which many of the materials to be collected are known to be disposed with respect to each other.

1. Common boulders, rolled pieces of rocks, or their fragments, pebbles, &c., picked up at random, in situations of no peculiar interest, are very seldom of any scientific utility; they had much better be left where they are, than made the source of embarrassment to those who are expected to arrange and incorporate them with objects of systematic geological or mineralogical collections. But boulders, rolled pieces, rubble-stones, and even gravel, sand, silt, and other loose materials, may prove objects of real scientific importance to the intelligent, although unscientific observer, in proportion as the nature and mode of their occurrence are ascertained, or appear to him to be connected with interesting circumstances and questions; such as their probable origin, and whether they may be considered as gradually washed down from higher levels by rains, rivers, &c.; or as

remnants of broken-up beds of lakes or seas (for both kinds have often been indiscriminately called alluvial), &c. He will often find them to contain well-preserved remains, such as teeth and bones of the elephant, hippopotamus, rhinoceros, petrified wood, &c. Also, interesting mineral substances, such as particles of metallic ores, gems, &c., are frequently found imbedded in those deposits of loose materials; let him carefully collect, label, and preserve such objects. With regard to loose blocks, specimens should in general be detached from such only, as, from the situation in which they are found, and from other circumstances, have evidently not formed part of neighbouring masses, and which are, therefore, called erratic blocks. Masses of cliffs and rocks precipitated from above, at recent periods, may, however, often supply the collector with good specimens of strata not easily accessible to him. Materials for roads, thrown out in heaps, may furnish specimens for collections; but the places from whence they are obtained should be previously ascertained. Road-stones are frequently brought from very distant quarries.

2. Upon the whole, rock specimens should be taken fresh from the masses in their native places. Among localities most favourable for this purpose, the following may be specified:—cliffs on the sea-shore—they frequently afford very perfect sections of the masses and strata of rocks; precipitous sides of rivers, and their beds, and of mountain streams, which often lay open strata and beds at depths otherwise difficult to discover; ravines and deep valleys transversely crossing the strata, and the naked sides of which, especially when long operated upon by rivers and mountain torrents, often present instructive profiles of stratification; artificial sections of ground, such as are produced by quarries, gravel-pits, and excavations, of every description, for roads, canals, tunnels, wells, &c.

3. Where mines are worked, the collector will generally find some well-informed person or other to assist him in his pursuits; but he should use circumspection in making purchases of specimens from the common miners.

4. Not unfrequently, one and the same mass of rock exhibits great diversity of aspect, through the variation which takes place in the mixture and proportion of its com-

ponent ingredients, their colour, &c. Also the texture, such as the crystalline-granular, the slaty, the compact, &c., are subject to variation, and gradual changes have often taken place through atmospheric influence, sometimes to a considerable depth into the mass. Accidental admixtures, not essential to the rock, are likewise frequently observable. As in such cases a few specimens would convey but an imperfect idea of the true character of the stratum, or other mass of rocks, suites of specimens should be formed, illustrative of most of the varieties which it affords.

5. The thickness of each stratum or bed, and other circumstances connected with them, such as their horizontality or inclination, and the angle under which, and toward what part of the compass they incline, should be regularly noted. Slight sketches of the stratification of a coast or cliff, marked with numbers corresponding to those on the labels of the specimens obtained from those strata, will be found greatly to abbreviate the trouble of writing descriptions on the spot.

6. Examine all places where coal-pits are sunk through different strata; procure specimens from these, and likewise of the different varieties of coal, paying particular attention to specimens of vegetable impressions which they, or any of the accompanying rocks, such as sandstone, &c., may afford.

7. No opportunity should be neglected to procure secondary fossils of every description, accompanied by specimens of the masses in which they are imbedded, and which are not seldom chiefly characterised by them. Interest should, therefore, everywhere be made with quarry-men, and persons engaged in all sorts of works of excavation, to preserve whatever may be found by them in the way of petrifactions, especially osseous remains; and those persons should be particularly cautioned against breaking to pieces whole skeletons, or large portions of them. If possible, the collector should in person superintend the excavation. The following suggestions, taken from Sir H. De la Beche's excellent treatise, "How to observe in Geology," particularly apply to osseous remains of an extremely delicate structure. Instead of endeavouring to extract these on the spot, the observer should detach so much of the rock as shall, to the best of his judgment, envelope the organic remain in

a protecting case suitable for the purpose of transport. Organic remains are generally in better condition, according to the little that is done to them prior to their final deposit in the Museum. If a fossil proves brittle to such a degree that the vibrations produced by blows to its matrix cause it to splinter up, the splinters, if sufficiently large, may be re-adjusted; but it is most advisable, on seeing a fossil begin to splinter, to take some stiff clay, if such can be procured, and press it down upon it. Wax, or similar materials, might advantageously be employed for this purpose, with small specimens. With regard to objects of great rarity and importance, and which rest exposed in a very friable rock, it it may even be desirable to prepare plaster of Paris on the spot, and cover the fossil (such as the skeleton of a saurian, &c.,) with a thick coating of it. By this process the exposed part of a skeleton is set, as it were, in a block of plaster, from which, after carefully working beneath it and the fossil in a friable rock, it may afterwards be freed, or in which it may be allowed to remain, as may be desired. When the scattered, yet well-preserved fossil bones of animals are found, it often happens that a large portion of the entire skeleton may be eventually obtained by diligent search. The accidental discovery of a small portion of bone rising through the rock may lead to that of entire skeletons, if sufficient care be employed. In many slaty rocks fishes, plants, and other organic remains abundantly occur among the laminæ, pressed down to so thin a substance as not readily to be seen in a cross fracture of the rock. When, therefore, such organic remains are suspected to exist in a schistose rock, detached portions of it should be struck so as to lay open the stones in the direction of the laminæ. In this way multitudes of fossil plants may be obtained, of which there were few traces in the cross-fracture of the rock.

8. Wherever deposits of secondary fossils are observed, it is of importance to note any striking circumstances relative to their mode of occurring; the proportion, for instance, in which the several species are distributed; whether they are more abundant in one bed of the rock than in another; whether they are dispersed in a confused manner through the mass, or arranged parallel to the general stratification, or confined to the surface of any particular stratum; or,

with regard to their individual position, whether shells for instance, are found all exhibiting the same view; or if fishes affect a general uniform position or parallelism of their sides to the stratification; and such other peculiarities as cannot generally be exemplified even by whole suites of specimens.

9. Uncommonly interesting are the osseous remains of caverns and grottos which frequently occur in limestone rocks; these should be diligently sought after and visited, even where report may represent them as not being ossiferous. The collector, in his examination, should proceed systematically by cutting through the layers of the incrustations which he may find at the bottom of them, and which are formed by the dripping down of water impregnated with calcareous particles; let him form a series of specimens from the layers of this stalagmitic deposit; as likewise of the alluvial matter beneath it, of the gravel, sand, and mud, which usually envelop the osseous remains. Of these latter he should form a complete series, not only as regards the natural difference he may observe in the several bones, but likewise the accidental changes observable in them, such as appearances of being gnawed, fractured, &c. Also other objects which may be found near to, or accompanying the bones, such as rounded concretions, fragments of stones different from the rock of the cave should be collected, and their manner of occurring noted on the labels. In the same manner the collector should not neglect recording every circumstance which the specimens alone are not calculated to illustrate, such as the distribution of the various bones in the caverns, their relative abundance, &c. He should also make memoranda relative to the nature and situation of the cavern itself, its direction, its dimensions, the presence or absence of water in it;—or whether it be furnished with fissures, particularly vertical ones; and if so, whether these be partly open, or filled with bones and rubble cemented together; whether parts of the sides near the opening exhibit a polish as if produced by rubbing against; together with other appearances which are likely to strike an attentive observer.

If fissures in limestone rocks should, on examination, prove to be filled with osseous remains, cemented together by calcareous and other matter, it will be desirable, for the

purpose of ascertaining whether bones of different animals are found at different depths, to extract them from the lower as well as the higher portions of the fissure, and carefully to note the succession of the several specimens thus obtained.

10. Where petrifying sources, as they are called, occur, or waters impregnated with calcareous and other matter, thrown down and consolidated into masses enveloping branches and other parts of vegetables, &c., the collector should, together with specimens, obtain any information within his reach, relative to the condition under which such deposits have been, or continue to be formed. In general it is also desirable chemically to examine such, and other waters remarkable for any striking peculiarity. They may readily be transmitted in clean, strong bottles tightly closed, sealed, and labelled.

11. In tracts of country where volcanos are in action, especially if still unexplored by geologists, not specimens only should be collected, but likewise all the historical data that can be obtained relative to the different eruptions and other phenomena connected with them; and all such circumstances should be noted as in any manner relate to the nature and appearance of those volcanos—their situation, form, craters, &c.; together with every particular concerning the lava-currents, their heat before consolidation, their direction, &c., and perfect suites should be formed of the various volcanic ejections. In endeavouring to detach specimens from a current of lava, the collector should not confine himself to the upper crust of scoriæ; but should likewise obtain fragments from the middle and lower beds. Ashes and other pulverulent volcanic matter are best preserved in strong bottles. Where they are found to enclose organic or other objects, these should be particularly attended to.

12. With regard to certain other rocks, to which the term trappean is applied, and which are now likewise generally considered as igneous, or as having been propelled, when in a state of fusion, through various rocks which they overlie, the collector, under the supposition that he is not altogether unacquainted with some of these rocks, such as basalt and porphyry, is desired to direct his attention to any alteration that may be observable in the condition of the strata in immediate contact with them. These conditions relate to

change of colour, lustre, texture, partial fusion or vitrification, &c., and many of them may be illustrated by suites of specimens carefully and judiciously selected.

13. An enumeration of the several instruments required by the geological traveller, for determining the direction and inclination of the strata, for measuring heights, &c., as likewise those for mineralogical investigation, would be superfluous to the proficient in geology and mineralogy, and of no avail to the less scientific collector, who, if he wish for information, is necessarily referred to treatises on those sciences. It is, however, otherwise as regards that indispensable implement, the hammer. Two of these, at least, are required; one weighing from two to four pounds and a half, for breaking the masses; the other of smaller dimensions, for trimming the specimens. Common hammers are not fit for the purpose; they should be of well-tempered steel, the handles of very tough wood, and most firmly inserted in the heads. The diagrams here given represent those more commonly used, and which may be had of Messrs. R. and G. Knight, Foster-lane, London. Figs. 1 and 2 are

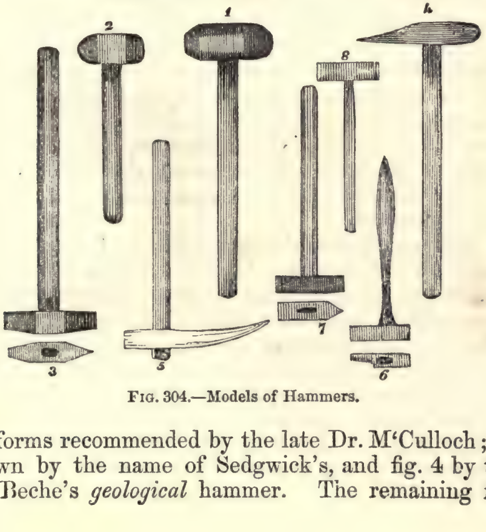


Fig. 304.—Models of Hammers.

of the forms recommended by the late Dr. M'Culloch; fig. 3, is known by the name of Sedgwick's, and fig. 4 by that of De la Beche's *geological* hammer. The remaining figures

(except No. 5) are those of *mineralogical* hammers of various forms and dimensions. A few mason's chisels, of various sizes, and a small miner's pick, fig. 5, will be found useful. A glove of thick leather for the left hand, on which the specimens are trimmed; and for their conveyance, a bag (likewise of leather), thin and cartridge paper for packing, small pieces of paper ready cut for labels, and paste or thick gum-water to affix the numbers to the specimens, constitute, together with wool and cotton for delicate secondary fossils, minerals, &c., all the apparatus needful to those who undertake the task of collecting.

14. No particular rules can be given for the operation of breaking, trimming, and fashioning rock-specimens; but the skilful management of the hammer, though some patience and practice be required, is by no means of difficult acquisition.

Specimens intended for public collections, generally speaking, should be of rather large dimensions; some masses, especially compound rocks, such as conglomerates, &c., cannot, in all their characteristic parts, be studied from diminutive fragments. A convenient size is four, to four and half, by three inches, and three quarters of an inch to one inch in thickness. Regularity of shape considerably facilitates the proper and safe packing of the specimens. Trim and fashion them on the spot, where there is abundance of materials; what you intend to be the finishing blow with your hammer will sometimes spoil a specimen. All the surfaces must exhibit a fresh fracture, except where it is desirable to illustrate disintegration through atmospheric and other influences; in which case more than one specimen should be obtained.

15. Each object should have its number affixed by means of thick gum-water or paste, and be accompanied by a ticket on which the exact locality is given, together with such information relative to the nature of the masses from which it is taken as the specimen alone is not calculated to convey:—whether they occur in distinct concretions, columnar, &c.; or, if stratified, what is the thickness of the stratum, its inclination to the horizon, &c. The numbers on the specimens may, at the same time, correspond with those of the notes of his road-book, if such be kept by the collector.

16. Great care should be bestowed on the proper packing of the objects. Each specimen is to be wrapped up in two papers; the inner soft, and less substantial than the outer. Put at the bottom of the packing-case a layer of hay, chaff, moss, or other soft substance, perfectly dry. Place on it the specimens edgewise and in close contact with each other, so that nothing can displace them. Fill up the interstices with moss or tow, and place the other specimens in the same manner, layer upon layer, until the box is nearly full, when the remaining vacuities are to be closely filled up with the same moss, &c., before the lid is fastened. The use of saw-dust for this purpose is not to be recommended. Loose fragile shells and other small delicate objects are best packed by putting them, enveloped in cotton, in rows, and rolling these up in sheets of stiff paper.

17. Still greater care is to be bestowed on such mineralogical specimens as present delicate crystallisations. These, after being wrapped up loosely in silk paper, should be put up separately in a chip-box each, and the empty space filled up with cotton. The chip-boxes are to be placed at the bottom of the packing-case. Minerals, not soft or brittle, may be wrapped up and packed nearly in the same manner as geological specimens. They are to be placed upright in rows one above the other, and with their principal surfaces parallel to two opposite sides of the packing-case. The weight of such case for land-carriage, or shipping, should not exceed one hundred weight.

18. As the geological collector cannot be expected to discover, in his excursions, many specimens of simple minerals desirable to be placed in the national collection, he will do well, if he fall in with persons acquainted with, and in the habit of procuring such, to secure their services, with a view to obtain all mineral substances that are peculiar to any particular colony or tract of country; or that claim attention on the score of their superior beauty and perfection of crystallisation. This latter character should be particularly attended to; it is, however, to be observed, that minerals not presenting it, may nevertheless prove highly interesting in other respects, and that a remarkable locality alone may often lend importance to a mineral which is abundantly met with at home.

In addition to the foregoing instructions by M. König, the student should be informed that in collecting fossils from the Silurian, Devonian, carboniferous, permian, triasic, and oolitic groups, the rock should be removed as much as possible from the shell or coral, on the spot; any fragments of the fossil that may have been broken off should be carefully collected and folded in thin, soft, paper, along with the specimen to which they belong: on returning home from the excursion, the fragments should be cemented in their proper places with a thick mucilage of gum arabic; the specimens may, afterwards, be cleaned and reduced to a convenient size for the cabinet: it is always desirable to preserve some fossils embedded in a portion of the rock in which they are found, to facilitate reference, and decide the stratigraphical position of the specimen. In the case of cretaceous fossils, the best cement we know is the following:—Dissolve a few pieces of gum mastic in as much spirits of wine as will make them liquid. In another vessel dissolve as much isinglass (previously soaked in warm water until softened) in rum, brandy, or spirits of wine, as will make two ounces, by measure, of strong glue: add two bits of powdered galbanum or ammoniacum. Mix the whole with a sufficient heat, and keep the composition in a well-corked, wide-mouthed bottle. When the cement is required for use, the bottle must be immersed up to the neck in a cup of hot-water. This compound is used by the most experienced, practical palæontologists, for cementing the fishes, crustacea, mollusca, and echinodermata of the chalk; we have found it, likewise, most valuable for uniting tertiary reptilian and mammalian bones. Tertiary fossils are usually very delicate and brittle: the Isle of Wight and Barton shells are, in general, in good preservation; those from Bracklesham Bay, however, from having been exposed to the action of sea-water, are soft and much decayed; they should be removed from the bed with a considerable portion of the clay and sand, and dried in the sun; afterwards, saturated with a thin mucilage of gum tragacanth (a quarter of an ounce of the gum to six ounces of cold water), prepared a week or ten days previously: after the shell is set with this preparation, the clay or sand may be removed. This mucilage is a most valuable agent for coating many other fossil shells disposed to decay, and likewise the bones and teeth of mammalia. Tertiary shells travel best packed in light toy-boxes,* disposed in the following manner:—First cover the bottom of the box an inch and a half deep with dry bran; then place a layer of shells nearly of one size, well embedded in the same; cover them with another layer of bran, and repeat the process until the box is *quite* filled. Small boxes thus packed should afterwards be put into a case, and well wedged into the same with waste paper. The most delicate specimens may be transmitted in this way without fear of injury.

T. W.

* May be obtained, in nests, from Evans and Sons' toy-warehouse, 116, Newgate-street, London.

GLOSSARY

OF SCIENTIFIC TERMS USED IN THE WORK.

ACASTA, one of the Oceanides.

ACEPHALA, mollusca wanting the head, as the scallop, &c.

ACERA, without a horn.

ACHATINA, a genus of univalve shells.

ACICULAR, needle-like, sharp-pointed.

ACROLEPIS, fossil fish with crested scales.

AEROLITES, mineral masses that fall from the atmosphere.

ALASMIDONTA, without a lateral tooth.

ALGÆ, a division of cryptogamic plants, including the sea-weeds.

ALLUVIUM, materials transported and deposited by the action of water.

ALUMINOUS, clayey.

ALUMINUM, metallic base of clay.

AMMONITES, *Ammon*, a name of Jupiter.

AMMONOCERATITES, the horn of Ammon.

AMORPHOUS, shapeless, destitute of regular form.

AMPHIDESMA, ligament, external and internal; a genus of shells.

AMPHITRITE, one of the Nereids.

AMPULLARIA, *lat.*, *ampulla*, a wide-mouthed bottle.

AMYGDALOID, that cellular structure of the trap-rocks, in which mineral substances are embedded.

ANALOGUE, a similar representative animal or vegetable; a recent shell of the same species as a fossil shell is an analogue of the latter.

ANASTOMA, mouth looking upwards.

ANASTOMOSING, running into each other.

ANATIFERA, producing ducks.

ANATINA, *anas, gr.*, a duck.

ANCHYLOSED, joints of bones, immoveably united.

ANCILLARIA, from *lat.*, *ancilla*, a damsel.

ANCYLUS, *lat.*, *ancile*, a sacred shield.

ANGLE: the following observations may be advantageously borne in mind: A right angle is formed by the insertion of two lines which are perpendicular to each other, and which form an angle of 90 degrees, or the fourth part of a circle; the frames which contain a pane of glass are an example: An acute angle is one which is less than 90 degrees; an obtuse angle, one which is more; an oblique angle is one which is not 90 degrees, and may be either more or less, either obtuse or acute.

ANNELIDES, animals having an external integument formed of rings, as the worm.

ANODONTA, having no teeth.

ANOMIA, without law, anomalous.

ANTENNÆ, the projecting feelers of insects.

Anthozoa, animal-flowers, as the Actinia.

Anthracite, stone-coal.

Anthracotherium, a pachydermatous animal, first found in a bed of anthracite.

Anticlinal axis, where the strata diverge from each other in opposite directions.

Apteryx, destitute of wings, applied to a particular genus of bird.

Arborescent, tree-like.

Arca, a chest, or ark.

Arenaceous, composed of sand.

Arenicola, inhabiting the sand.

Argillaceous, composed of clay.

Argonauta, sailors in the ship Argo; a genus of the cephalopoda.

Articulata, animals without an internal skeleton, and having jointed coverings, as insects.

Arundinaceous, (*arundo,* a reed,) plants of the reed tribe.

Ascidian, shell-less molluscs, shaped like a bottle.

Aspergillum, a watering-pot.

Astræa, a genus of corals.

Augite, a mineral resembling hornblende, of dark-green or black colour, occurring in volcanic rocks.

Auricula, a little ear.

Avicula, a little bird.

B.

Baculites, *lat., baculum,* a staff.

Balanus, an acorn.

Barytes, a mineral substance, also called heavy spar.

Basalt or Trap, a mineral composed of augite and feldspar.

Basin, a depression of strata, in which accumulations of more modern date are deposited.

Batrachian, allied to the frog, toad, &c.

Belemnite, a long, dart-shaped fossil (whence its name), the dorsal bone of an extinct kind of *sepia,* or cuttle-fish.

Belemnites, a dart.

Bifid, divided into two parts, or forked.

Bilobed, divided into two lobes.

Birostrites, double-beaked.

Bitumen, mineral pitch, an essential element of good coal.

Blocks, erratic, a term equivalent to boulders, applied to transported masses of primary rocks.

Brachial, belonging to the arm.

Brachiopoda, arm-footed; molluscous animals, whose organs of locomotion consist of arm-like processes.

Branchia, aquatic organs of respiration, as gills.

Breccia, a term adopted from the Italian to designate a mass composed of angular unworn fragments of rocks, as conglomerate is formed of worn and rounded materials.

Bryozoa, *moss-animals;* polypes that encrust other bodies, as *Flustræ.*

Buccinum, a trumpet; a genus of shells.

Bulimus, a genus of shells.

Bulla, a bubble.

Bullæa, like bulla.

C.

Calcaire grossier, a series of marine tertiary limestones, occurring in the vicinity of Paris.

Calc sinter, deposition from thermal springs charged with carbonate of lime.

Calcareous, applied to rocks and other substances, of which lime is the base.

Calcedony, a form of silex, so named from the city of Calcedon, in Asia, where it abounds.

Calceola, a little shoe; a genus of shells.

Calcium, metallic base of lime.

Calyptræa, a cap for the head; a genus of shells.

Campanularia, arborescent corals, with bell-shaped cells.

Cancellaria, *lat.*, *cancelli*, like pales of a fence; a genus of shells.

Cancellated, the cellular structure of a bone.

Capsa, a coffer, or box; a genus of shells.

Capsule (*socket*), the hollow or concavity of a bone which receives the head of another bone.

Carbon, the elementary constituent of charcoal and the diamond.

Carbonate of Lime, the combination of lime and carbonic acid: all limestones and marbles are so composed.

Carboniferous, producing coal; a term improperly applied to the rock also called mountain limestone.

Cardita, allied to cardium; a genus of shells.

Cardium, a heart; a genus of shells.

Carinaria, *lat.*, *carina*, the keel of a vessel; a genus of gasteropods.

Carneous, fleshy.

Carocolla, *gr.*, *caracalla*, a kind of hood.

Caryophyllia, branched stellular coral.

Cassidaria, allied to cassis; a genus of shells.

Cassis, a helmet; a genus of shells.

Castalia, name of a daughter of Achelous.

Caudal, belonging to the tail.

Centrifugal, a force directed from the centre to the circumference.

Cephalic, belonging to the head.

Cephalopoda, mollusca whose organs of locomotion are arranged round the head.

Cerithium, *cerites*, a wax-coloured gem; a genus of shells.

Cervical, belonging to the neck.

Cetacea, an order of mammalia, inhabiting the sea; whales.

Chama, pronounced *kama*, to gape; a genus of shells.

Chelæ, claws.

Chelonia, animals of the turtle tribe.

Chert, an impure variety of flint, frequently composed of silex and greensand.

Chiton, pronounced *kiton*, a coat of mail; a genus of shells.

Chitonellus, little chiton.

Choanite, a zoophyte of the chalk.

Cilia, hair-like vibratory organs.

Cirri, curled processes, as in the Barnacle.

Clausilia, *lat.*, *claudo*, to shut; a genus of shells.

Clavated, club-shaped.

Clavigella, *lat.*, *clava*, a club; a genus of shells.

Cleavage, a peculiar laminated structure in slate rocks.

Cleodora, name of a nymph; a genus of shells.

Clio, name of a nymph, and a muse; a genus of pteropoda.

Clymene, one of the Nereids; a genus of the cephalopoda.

Coleoptera, insects having wing-cases, as beetles.

Columbella, *lat.*, *columba*, a little dove.

Conchoidal, shelly.

Concholepas, conch like a lepas; a genus of shells.

Concretion, a combination of separate particles.

Condyle, an articulated surface or joint.

Conformable, applied to strata lying parallel to each other.

Conglomerate, a mass composed of rounded water-worn fragments, cemented together; as breccia is used to describe a similar aggregation of uneven and angular materials.

Coniferæ, trees bearing cones, containing the seeds, as the fir, pine, &c.

Conolites, *lat.*, from *conus*, a cone.

Conus, a cone; a genus of shells.

Corbis, a basket; a genus of shells.

Corbula, a little basket; a genus of shells.

Cordiform, heart-shaped.

Cornbrash, a coarse, shelly limestone of the oolite.

Coronula, *lat.*, *corona*, a crown; a genus of shells.

Corticiferous, belonging to the bark of a tree.

Cotyledons, seed-lobes of plants.

Crag, a provincial term, used to designate the tertiary deposits of Norfolk and Suffolk.

Crania, a skull; a genus of shells.

Crassatella, *lat.*, *crassus*, somewhat thick; a genus of shells.

Crater, the vent at the summit of a volcano.

Crateriform, having the form of a crater.

Crenatula, a little notch; a genus of shells.

Crenulated, notched or toothed.

Crepidula, *lat.*, *crepida*, a little shoe; a genus of shells.

Cretaceous, belonging to chalk.

Crinoidea, lily-shaped animals.

Cristellaria, from *crista*, *lat.*, crest, or tuft.

Crop out, signifying the emergence of a stratum on the surface.

Crucial, in the form of a cross.

Crustacea, animals having an external crust or skeleton, as the crab, lobster, &c.

Cryptogamiæ, a class of plants in which the organs of fructification or reproduction are concealed.

Crystals, symmetrical forms assumed by mineral substances.

Crystallised, is used to denote that perfect form of crystallisation, of which crystalline implies a less perfect degree. Both are frequently used indiscriminately.

Cucullæa, *lat.*, *cucullus*, a hood; a genus of shells.

Cupreous, coppery.

Cyathiform, cup-shaped.

Cycadeæ, a family of plants, natives of the Cape of Good Hope, and intermediate between the monocotyledonous and dicotyledonous classes.

Cyclas, orbicular; a genus of shells.

Cyclostoma, circular mouth; a genus of shells.

Cymbulia, *lat.*, *cymbula*, a little boat; a genus of shells.

Cypræa, *lat.*, *cypris*, a name of Venus; a genus of shells.

Cypricardia, allied to cyprina and cardium; a genus of shells.

Cyprina, from cyprus, consecrated to Venus; a genus of shells.

Cyrene, daughter to the river Peneus; *Cyrena*, a genus of shells.

Cytherea, a name of Venus; a genus of shells.

D.

Debris, the ruins or detritus of rocks and strata.

Deciduous, parts which are shed, as leaves of trees.

Delphinula, *lat.*, *delphinus*, a dolphin; a genus of shells.

Delta, alluvial deposits, formed by rivers.

Dendritic, branched, like a tree.

Dentalium, *lat.*, *dens*, a tooth; a genus of shells.

Denudation, the carrying away a portion of overlying materials by the action of water.

Dermal, belonging to the skin.

Desiccation, the act of drying.

Detritus, disintegrated materials of rocks.

Diceras, with two horns; a genus of shells.

Dicotyledonous, a grand division of the vegetable kingdom, applied to plants having two cotyledons, or seed-lobes.

Didelphys, a marsupial animal, allied to the opossum.

Dikes, the intrusion of volcanic among stratified rocks. The name is derived from the term applied in Scotland and the north of England to walls, owing to these ejections frequently presenting the appearance of walls, in consequence of the strata on both sides having been worn away.

Diluvium, a term employed at an early period of the science to designate ancient alluvial deposits.

Dip, the inclination of strata.

Diptera, insects having two wings.

Discoidal, in the form of a disc.

Discorbites, from *lat.*, *discus*, a disc, and *orbis*, an orb.

Dolabella, *lat.*, a little axe, or hatchet; a genus of shells.

Dolium, a tun; a genus of shells.

Dolomite, crystalline magnesian limestone.

Donax, a wedge; a genus of shells.

Druses, minute crystals, lining the cavities of minerals; as, for example, *drusy quartz* in the hollows of flint nodules.

E.

Earth's crust, that portion of the solid surface of the earth which is accessible to human observation.

Eburna, *lat.*, *ebur*, ivory; a genus of shells.

Echinodermata, hedgehog-skinned; applied to creatures having a prickly external integument, as the echinus, or sea-urchin.

Echinus, sea-urchin.

Edentulous, *toothless*, animals having no front teeth, as the Armadillo.

Elytra, wing-cases of insects.

Emarginula, *lat.*, *emarginatus*, a notched margin; a genus of shells.

Encrinite, a genus of lily-shaped animals.

Entomostracea, shelled crustaceans, as the Cyprides.

Eocene, dawn of the recent or existing period.

Ephemeron, the creature of a day.

Eroded, worn away.

Erycina, a surname of Venus; a genus of shells.

Escarpment, the steep side of a hill.

Estuary, the mouth of a river alternately occupied by the waters of the river and the sea.

Etheria, one of the sea-nymphs; a genus of shells.

Exuviæ, organic remains.

F.

Falun, a French term for the middle tertiary strata.

Fasciolaria, *fasciola, lat.*, a little band; a genus of shells.

Faults, an interruption of the continuity of strata.

Fauna, a term borrowed from the *fauni*, or rural deities of classic mythology, and now used to denote the animals, as the *flora* indicates the plants, of any given district.

Feldspar, a simple mineral entering into the composition of granite and several other igneous rocks.

Feldspathic, belonging to, or composed of, feldspar.

Ferruginous, impregnated with iron.

Fissurella, a little fissure; a genus of shells.

Fistulana, *lat., fistula*, a pipe.

Flora, a term employed to denote the plants of any particular region, as the term *fauna* indicates its animals.

Foliaceous, arranged like leaves.

Foramenifera, a division of animalcules having perforated shells.

Formation, a group or series of strata referred to a common date or origin.

Fossils, the mineralised remains of animals and plants.

Fossiliferous, containing fossils.

Frit, a frothy, spongy substance, arising from the imperfect calcination of certain minerals.

Fusus, a spindle; a genus of shells.

Fusiform, spindle-shaped.

G.

Galathea, name of a sea-nymph.

Galeolaria, *lat., galea*, a helmet.

Gasteropoda, molluscs with the locomotive organs on the under part of the body, as the snail.

Gastrochæna, body gaping; a genus of shells.

Gault, a provincial term for beds of blue clay, which, though strictly applicable only to those of the chalk formation, is locally applied to those of other deposits. Thus the clay beds of the oolite of Huntingdonshire are termed gault.

Gelatinous, jelly-like; semi-fluid like jelly.

Glacier, the accumulations of ice and snow in the alpine and other mountains.

Globose, globe-like.

Glycimeris, name of a shell.

Gneiss, a primary stratified rock.

Gorgonia, a genus of flexible arborescent corals.

Grallæ, (stilts,) applied to birds having feet like the heron.

Gramineæ, the family of plants composing the grasses.

Granules, little grains.

Greensand, Lower, the lowermost member of the chalk formation.

Greenstone, a variety of trap-rock, composed of hornblende and feldspar.

Greywacke, a term applied to rocks of conglomeritic character, bearing marks of induration by heat.

Grit, coarse-grained sandstone.

Gryphæa, with a hooked nose; a genus of shells.

Gypsum, a mineral composed of lime and sulphuric acid; sulphate of lime.

H.

Haliotis, the sea-ear; a genus of shells.

Hamite, hook-shaped. A shell of an extinct genus of cephalopoda.

Harpa, a harp; a genus of shells.

HELICINA, like helix; a genus of shells.

HELIX, a spiral line; a genus of shells.

HERBIVOROUS, living on herbs.

HIATELLA, *lat.*, *hiatus*, the little gaper; a genus of shells.

HIPPOPUS, horse's foot.

HIPPURITES, *lat.*, *hippuris*; a genus of shells.

HOLOPTYCHIUS, all wrinkle fish, in allusion to the corrugated scales.

HOMALONOTUS, a genus of trilobites, occurring in the Silurian deposits; so named by Mr. König, from the smoothness of the back.

HOMOLOGUE, the analogous organ in different animals.

HORNBLENDE, a simple mineral of a dark-green or black colour.

HYALÆA, a glass; a genus of gasteropods.

HYALINE, crystalline appearance, or pellucid.

HYDRA, freshwater polype.

HYDROZOA, coral polypes organised like the polype.

HYLÆOSAURUS, the lizard of the weald. An extinct lizard discovered by Dr. Mantell in the sandstone of that formation.

HYMENOPTERA, insects with four membranous wings.

HYPOGENE, a term used by Sir C. Lyell to denote the primary rocks, and signifying that they are formed beneath the surface.

HYRIA, a honey-comb; a genus of shells.

I.

ICEBERG, a term derived from the German, which literally means a mountain of ice, and is applied to the masses of that substance, often the size of hills, which float, partly in, partly out of the water, both in polar, northern, and southern seas.

ICHTHYOSAURUS, fish-like lizard; a gigantic marine reptile, partaking of the characters of the crocodile and the fish.

IGUANA, an existing lizard, a native of India, America, &c.

IGUANODON, a colossal, extinct saurian, discovered by Dr. Mantell in the wealden formation; so named from its teeth resembling those of the recent iguana.

IMBRICATED, placed one above the other, like the tiles of a house.

INCANDESCENT, a term applied to mineral masses in a state of fusion.

INDUCTION, the establishing a general conclusion from various individual facts.

INFUSORIA, microscopic animalcules generated in infusions.

INSECTIVOROUS, animals that live on insects, as the hedgehog.

INSPISSATED, dried up.

INVERTEBRATA, animals destitute of a spine or vertebral column, as the crab, worm, &c.

IRIDINA, *lat.*, *iris*, a rainbow.

ISOCARDIA, symmetrical heart; a genus of shells.

J.

JANTHINA, *lat.*, *ianthum*, a violet; a genus of shells.

JURA LIMESTONE, *calcaire jurassique*, strata of the oolitic series, which, constituting the mass of Mount Jura, derive, from this circumstance, the name by which they are best known on the Continent.

K.

KIMMERIDGE CLAY, a thick bed of bituminous clay, so called from Kimmeridge, in the Isle of Purbeck, where it chiefly occurs.

L.

LACUSTRINE, belonging to a lake.

LAMELLÆ, thin plates, like sheets of paper.

LAMELLATED, covered with thin plates, or scales.

LAMELLIFORM, shaped like a thin plate, or scale.

LAMINÆ, thin plates.

LAMINATED, arranged in thin plates.

LAPILLI, volcanic ashes, in which globular concretions prevail.

LAPLYSIA, a sponge that cannot be cleaned; a genus of gasteropoda.

LARVA, the first stage of an insect.

LAVA, the stone flowing in a melted state from a volcano.

LENTICULITES, *lat., lenticula,* a little lentil.

LEPIDOPTERA, insects having scaly wings, as moths.

LIAS, corrupted from layers. Employed to designate the formation intermediate between the oolite and new red sandstone.

LIGNITE, wood partially converted into coal.

LIMA, a file; a genus of shells.

LIMAX, a snail, or slug.

LIMACINA, *lat., limax.*

LINGULA, a little tongue; a genus of shells.

LITHODAMI, mollusca which perforate stones, shells, &c.

LITHOLOGICAL, used to denote the stony character of a mineral mass.

LITHOPHYTES, stone plants; a term applied to corals.

LITTORAL, belonging to the seashore.

LITUOLITES, *lat., lituus,* crooked trumpet; a genus of cephalopoda.

LOAM, a mixture of sand and clay.

LOESS, a tertiary deposit on the banks of the Rhine.

LOLIGO, for a cuttle-fish.

LOPHIDON, an extinct animal of the order Pachydermata, so named from the prominences on its teeth.

LOLIGOPSIS, like loligo.

LUCINA, name of a goddes; a genus of shells.

LUTRARIA, *lat., lutra,* an otter, from frequenting mud; a genus of shells.

LYCOPODIACEÆ, an extinct genus of plants, allied to the club-mosses, which occur on the moors and mountain-heaths of the north of England.

LYMNÆA, a genus of shells.

M.

MACROURA, long tail, applied to crustaceans, as the lobster.

MACROPOMA, *long operculum,* name of a fossil fish.

MACTRA, a kneading-trough; a genus of shells.

MADREPORE, (literally *mother of pores,*) a term descriptive of corals which have superficial, star-shaped cavities or pores.

MAGILUS, a genus of shells.

MALLEUS, a hammer.

MAMMALIA } animals which give
MAMMIFERA } suck to their young.

MAMMILLARY, a surface studded over with rounded projections.

MAMMILLATED, studded with mammillæ, or rounded protuberances.

MAMMOTH, the *elephas primigenius,* or primitive elephant.

Mandibles, jaws.

Mantle, the soft external envelope of the molluscs.

Marginella, *lat.*, *margo*, a margin, alluding to the outer lip; a genus of shells.

Marl, a mixture of lime and clay, of various degrees of hardness.

Marsupials, animals which carry their young in a pouch, as the kangaroo.

Marsupite, a zoophyte, allied to the crinoidea, occurring in the chalk.

Mastodon, an extinct animal, allied to the elephant, the name being derived from its having tuberculated teeth, from *μαστος*, a breast, and *οδους*, a tooth.

Matrix, the mass or substance in which a fossil is embedded.

Mechanical, applied to deposits of sedimentary, as distinguished from those of igneous origin.

Medullary, applied to the central pith of plants, and the vertebral canal of animals.

Megalonyx, great-clawed animal, allied to the sloth.

Megalosaurus, great lizard: an extinct gigantic carnivorous reptile.

Megatherium, an extinct colossal quadruped, allied to the sloth.

Melania, black; a genus of shells.

Melanopsis, like melania; a genus of shells.

Meleagrina, a guinea-fowl.

Melonites, *lat.*, *melo*, a melon.

Metamorphism, or Metamorphosis, the change induced in strata by exposure to a high temperature.

Mica, a simple mineral, one of the component parts of granite.

Micaceous, containing mica.

Miliolites, *lat.*, *milium*, millet; forameniferous shells.

Miocene, middle tertiary strata.

Mitra, a mitre; a genus of shells.

Modiola, a little measure, or bucket; a genus of shells.

Molares, the double or grinding teeth.

Molecules, microscopic particles.

Mollusca, animals with soft bodies, destitute of bones.

Monads, the minutest infusorial animalcules.

Monitor, a lizard, found both recent and fossil.

Monoceros, one-horned; a genus of shells.

Monocotyledonous, a grand division of the vegetable kingdom, founded on the plant having but one cotyledon, or seed-lobe.

Monodonta, one tooth; a genus of shells.

Moraine, an accumulation of débris formed in valleys by glaciers.

Multilocular, applied to many-chambered shells, as the nautilus, and ammonite.

Multivalve, shells composed of many pieces, as the chiton.

Murex, a shell producing purple; genus of shells.

Muschelkalk, a shelly limestone of the triasic system.

Mya, a mussel; a genus of shells.

Mytilus, for a kind of mussel; a genus of shells.

N.

Nacreous, pearly.

Natica, adapted for sailing; a genus of shells.

Nautilus, *lat.*, *nauta*, a sailor; a genus of shells.

Navicella, *lat., navicula,* a little boat; shell of infusoria.

Nerita, hollow; a genus of shells.

Neritina, like nerita; a genus of shells.

Neuroptera, insects having wings finely nerved, as the dragon-fly.

Nodosaria, *lat., nodus,* a knot.

Nodule, a rounded irregularly-shaped mass, as a flint.

Normal, regular or legitimate; thus normal form means regular or legitimate form.

Nucleus, the centre or point around which other matter is collected.

Nucula, a small nut; a genus of shells.

Nummulite, an extinct many-chambered shell, resembling a coin; *lat., nummus,* whence its name.

Nummulites, *lat., nummulus,* a small coin.

O.

Obsidian, volcanic glass.

Occiput, the back part of the skull.

Octopus, a foot; a genus of cephalopoda.

Oliva, an olive; a genus of shells.

Onchidium, a genus of gasteropoda.

Oolite, limestone composed of an aggregation of spheroidal, egg-like particles.

Operculum, *a lid;* applied to the gill-covering in fishes, and the plate that closes the aperture in univalve shells.

Ophidian, the snake and serpents.

Orbicula, a little ball; a genus of shells.

Orbiculina, *lat., orbiculus,* a little orb; a genus of foramenifera.

Orbitulites, *lat., orbis,* an orb; a genus of corals.

Ornithorynchus, a genus of animals having the mouth produced into a beak, like a bird.

Orthocera, straight horn; a genus of cephalopoda.

Orthoceratite, a straight many-chambered extinct shell.

Ossicula, minute bones.

Ostrea, an oyster.

Otion, a little ear; a genus of cirrhipoda.

Outliers, detached portions of a main mass of strata.

Ovate, egg-shaped.

Oviparous, animals which bring forth eggs.

Ovula, *lat., ovum,* an egg; a genus of shells.

Oxyde, the combination of oxygen with a metal.

Oxygen: for a complete explanation, consult various works on chemistry. The beginner may be contented with knowing, that it constitutes the vital portion of the atmosphere, and enters so largely into the composition of rocks, as to constitute a considerable part of the solid strata of the earth.

P.

Pachydermata, an order of animals, including the elephant, rhinoceros, horse, pig, &c., distinguished, as their name, which is derived from the Greek, imports, by having thick skins.

Palæontology, the science which treats of extinct animals.

Palæotherium, an extinct quadruped, allied to the tapir.

Paludina, a freshwater shell, of snail-like shape.

Paludina, *lat., palus,* a marsh.

Pandora, alluding to Pandora's box.

Parietes, the walls of the cavities in animals.

Panopæa, all aperture; a genus of shells.

Parmacella, *lat.*, *parma*, a little shield; a genus of gasteropoda.

Parmophorus, shield-bearing.

Patella, a bason, the knee-pan; a genus of shells.

Pecten, a comb; a genus of shells.

Pectinaria, from *pecten*, a comb.

Pectinated, toothed like a comb.

Pectunculus, a genus of shells.

Pediform, shaped like a foot.

Pedum, a shepherd's crook.

Peduncle, a stalk or support.

Pelagic, } belonging to deep seas.
Pelagian, }

Peperino, a volcanic conglomerate.

Perna, a gammon of bacon, a pig's foot; a genus of shells.

Petricola, inhabiting rocks.

Petroleum, mineral oil.

Phasianella, a little pheasant; a genus of shells.

Pholas, a burrow, to pierce; a genus of shells.

Phyllidia, a genus of gasteropoda.

Phylliroe. do., do.

Physa, a genus of shells.

Pileopsis, like a bonnet; a genus of shells.

Pinna, a plume, or feather; a genus of shells.

Pinnate, shaped like a feather, or fin.

Pirena, the point of a sword; a genus of shells.

Pisolitic, pea-like; resembling peas, agglutinated together.

Placentula, a little cake.

Placuna, a broad table; a genus of shells.

Plagiostoma, an oblique mouth; a genus of shells.

Planaxis, flattened axis?

Planorbis, flat orb; a genus of shells.

Planorbis, a freshwater shell, of discoidal form.

Plesiosaurus, an extinct fossil genus of saurian or reptiles, approximating more closely to the lizard than the fish, as the ichthyosaurus approaches more nearly to the fish than the lizard.

Pleurobranchus, branchiæ at the side; a genus of shells.

Pleurotoma, having the edge cleft; a genus of shells.

Plexus, a bundle of vessels.

Plicatula, *lat.*, *plica*, a little fold, or wrinkle; a genus of shells.

Pliocene, the newer groups of the tertiary formations.

Plumose, feather-like.

Pneumodermon, skin-like lungs; a genus of pteropoda.

Podopsis, like a foot.

Pollicipes, *lat.*, *pollex*, the thumb, and *pes*, the foot; a genus of cirrhipoda.

Polygyra, many whorls.

Polyparia, corals.

Polystomella, many-mouthed.

Porphyry, an igneous rock.

Pozzuolana, volcanic ashes.

Precipitate, the chemical deposit of a substance held in solution by water.

Producta, an extinct bivalve shell, found in the lower secondary rocks.

Psammobia, living in sand; a genus of shells.

Pterocera, horned wing; a genus of shells.

Pterodactyle, an extinct winged reptile.

Pterotrachea, winged trachea.

Ptychodus, *wrinkle-tooth* fish.

Pumice, light, spongy, porous lava.

Pupa, a puppet.

Purpura, a shell producing purple.

PYRAMIDELLA, a pyramid; a genus of shells.

PYRGOMA, a tower; a genus of cirrhipoda.

PYRIFORM, pear-shaped.

PYRITES, sulphuret of iron, a compound of sulphur and iron.

PYROGENOUS, igneous, applied to ancient melted rocks.

PYRULA, a little pear; a genus of shells.

Q.

QUADRUMANA, *four-handed*, the monkey-tribes.

QUA-QUA-VERSAL DIP, the dip of beds, from a common centre to all points of the horizon.

QUARTZ, a simple mineral, composed of silex, in its purest form.

QUARTZOSE, rocks composed of silex, or flint.

R.

RADIATA, the lowest primary division of the animal kingdom; as the echinoderms, polyparia, &c.

RADIOLITES, *lat.*, *radius*, a ray; a genera of shells.

RAMOSE, branched.

RANELLA, a little frog; a genus of shells.

RENIFORM, kidney-shaped.

RENULITES, *lat.*, *ren*, a kidney.

RETICULATE, resembling net-work.

RHOMB, a quadrilateral figure, of diamond-like shape, having its four sides equal.

RHOMBOID, a similar figure, having only two sides equal.

RICINULA, like the castor-oil seed.

RODENTIA, gnawers: an order of animals having a peculiar dentition, as the rabbit, hare, squirrel, rat, &c.

ROSTELLARIA, a little beak; a genus of shells.

ROTALITES, *lat.*, *rota*, a wheel; a genus of foramenifera.

ROTELLA, a very small wheel; do.

RUBBLE, fragmentary beds of stone.

RUMINANTIA, *lat.*, *rumino*, animals which chew the cud or ruminate as the ox, deer, &c.

S.

SABELLARIA, *lat. sabellum*, coarse sand.

SANGUINOLARIA, *lat.*, *sanguis*, blood; a genus of shells.

SAURIAN, an animal, belonging to the lizard tribe.

SAXICAVA, *lat. saxum*, a rock, and *cavo*, to hollow; a genus of shells.

SCALARIA, a flight of stairs; a genus of shells.

SCAPHITE, extinct genus of cephalopoda, of a boat-like form.

SCHIST, the same as slate, from the Greek σχίζω, to split, in allusion to the facility with which rocks of this texture may be divided or split.

SCORIÆ, volcanic cinders.

SECULAR, used to describe the vast periods of geological changes. Thus secular refrigeration indicates the succession of ages, during which our planet has cooled down from its presumed original state of fluidity, to its present solid condition.

SEDIMENTARY, deposited as a sediment by water.

SEGREGATION, a chemical separation of mineral substances.

SEPIA, *lat.*, *sepio*, to cover or conceal; a genus of cephalopoda.

SEPTA, partition, as in the shells of the nautili.

Septaria, *lat.*, *septum*, a division.

Septaria, nodules of clay, having their crevices filled with spar, and frequently with some organic substance, as a nucleus, in the centre.

Serpentine, a rock, the name of which is derived from its stripes and markings frequently resembling the skin of a serpent. In its normal form it is composed of diallage and magnesia.

Serpula, a serpent; a genus of annelida.

Serrated, toothed like a saw.

Sertularia, a genus of arborescent corals.

Shale or Schist, indurated slaty clay.

Siderolites, *lat.*, *sidus*, a star.

Sigaretus, a genus of gasteropods.

Silex, flint.

Silica or Silicon, the base of flint.

Siliceous, flinty.

Silicified, changed to flint.

Siliquaria, *lat.*, *siliqua*, a bean-pod; a genus of shells.

Silt, the comminuted detritus transported by rivers.

Sinter, a precipitate from mineral springs.

Solarium, a sun-dial; a genus of shells.

Solen, a pipe or tube; a genus of shells.

Solenomya, allied to solen and mya.

Spatangus, a genus of sea-urchins.

Spathose, opaque.

Sphærulites, *lat.*, *sphærula*, a little globe; a genus of shells.

Spheroidal, obtuse, or having the form of a spheroid.

Spicula, sharp-pointed processes.

Spirolinites, *lat.*, *spirula.*

Spirorbis, a spiral orb.

Spirula, a little spire.

Spondylus, head of a prickly artichoke; a genus of shells.

Squamous, arranged like scales.

Stalactite, the dripping of carbonate of lime.

Stalagmite, the same substance dropped on the earth.

Stellular, having star-like forms.

Sternal, relating to the sternum or breast-bone.

Sternum, the breast-bone.

Stomatella, a little mouth.

Stomatia, like a mouth.

Stratified, deposited in layers or strata.

Stratum, a layer of any deposit.

Strike, the direction or line of bearing of strata, which is always at right angles to the dip.

Strombus, a sort of shell-fish; a genus of shells.

Struthiolaria, an ostrich.

Stufas, volcanic vents emitting gases and vapours.

Succinea, amber-coloured.

Syenite, a variety of granite, in which hornblende supplies the place of mica; so named from the city of Syene in Egypt, where it occurs.

Symphinota, united at the back.

Synclinal Axis, the reverse of anticlinal, the point at which the strata converge towards each other.

T.

Tellenides, like tellina.

Tellina, the name of a swift fish.

Tentacula, feelers.

Terebella, a little auger.

Terebellum, a little auger.

Terebratula, *lat.*, *terebratus*, pierced.

Teredina, resembling teredo.

Teredo, a worm that bores wood.

Tertiary, ancient formations, but newer than the chalk.

Testacea, molluscous animals, as snails and whelks, scallops and

oysters, which have a shelly covering, of which others are destitute.

TESTACELLA, a little shell.

THERMAL, hot.

THORACIC, belonging to the chest or thorax.

TORNATELLA, *lat.*, *torno*, to turn in a lathe.

TRACHYTE, a variety of lava composed of feldspar, and often containing crystals of glassy feldspar. It frequently passes into other varieties of igneous rock.

TRAP, volcanic rocks composed of feldspar, augite, and hornblende.

TRAVERTINE, crystalline tufaceous limestone.

TRICUSPID, having three points.

TRIDACNA, three bites.

TRIDACTYLE, three-fingered.

TRIGONIA, three corners.

TRILOBATE, three-lobed.

TRILOBITES, an extinct family of crustacea, having the back usually divided into three lobes.

TRITON, a sea deity.

TROCHUS, a child's top.

TUBICINELLA, a little trumpet.

TUFA, calcareous deposit from incrusting streams.

TUFF, earthy volcanic rock.

TURBINATED, top-shaped, in form of an inverted cone.

TURBINELLA, like a wreath.

TURBO, *lat.*, a wreath.

TURRILITES, *lat.*, *turris*, a tower.

TURRITELLA, a little tower.

U.

UMBRELLA, a little shade.

UNCONFORMABLE, strata lying in a different position from those on which they rest, or which rest on them.

UNGULATA, hoofed.

UNGULINA, *lat.*, *ungula*, a hoof.

UNIO, a pearl.

UNIVALVE, shell composed of but one piece.

V.

VALVATA, *lat.*, *valva*, a folding-door.

VEINS, fissures in rocks filled up by extraneous substances, either earthy or volcanic.

VENERICARDIA, allied to Venus and cardium.

VERMES, worms.

VERMETUS, *lat.*, *vermis*, a worm.

VERMIFORM, worm-shaped.

VERMILIA, *lat.*, *vermis*, a worm.

VERTEBRATA, a great division of the animal kingdom, all which are furnished with a back-bone, as mammalia, birds, reptiles, and fishes, as distinguished from mollusca, articulata, crustacea, zoophytes, and insects, which have none.

VERTICILLATE, arranged in whorls.

VESICULAR, full of vesicles or cells.

VILLI, processes in animal structures, resembling the pile of velvet.

VITRIFACTION, the fusion of a substance into glass by heat.

VITRINA, *lat.*, *vitrum*, glass.

VIVIPAROUS, bringing forth live young.

VOLVARIA, *lat.*, *volvo*, to roll.

VOLUTA, a volute, or scroll.

VORTICIALIS, *lat.*, *vortex*, a whirlpool.

VULSELLA, tweezers.

Z.

ZOOLITE, peculiar minerals found in volcanic rocks.

ZOOLOGY, the study of animals.

ZOOLOGICAL, relating to animals.

ZOOPHYTES, animal vegetables; a term incorrectly applied to corals and other animals, supposed to resemble plants in form.

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